Быстротные (η_1,η_2) корреляции частиц с разными зарядами и возможная кластерная природа источников в PbPb столкновениях

В. Л. Коротких

на основе доклада J.Jia “**Forward-backward multiplicity correlations in PbPb, pPb and pp collisions from ATLAS**”, JiangyongJia_**qm2015**
и доклада на семинаре CERN
http://cds.cern.ch/record/2055672, ATLAS-CONF-2015-051

Geometry Really Matters

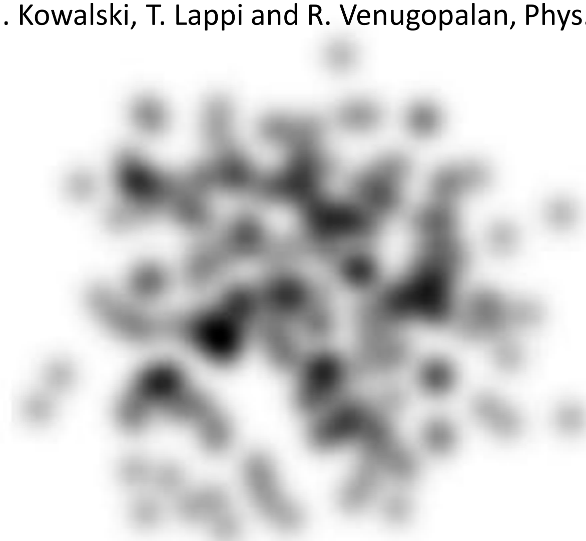
Strong interactions build space-momentum correlations leading to a hubble expansion

Sorensen, QM2012

The system remembers the geometry

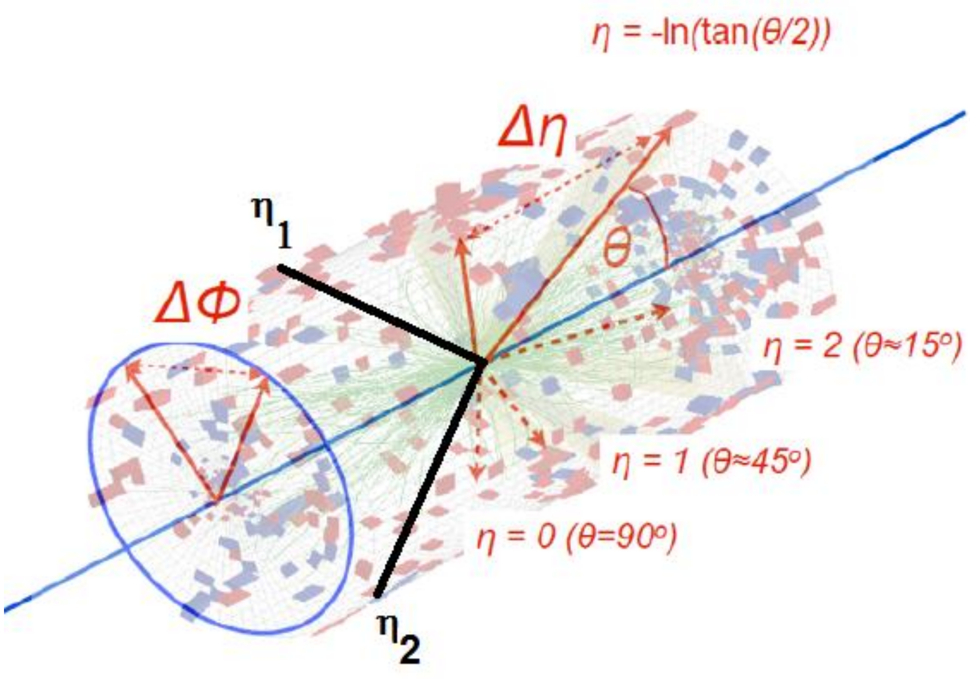
This is a more detailed view of the initial conditions

H. Kowalski, T. Lappi and R. Venugopalan, Phys.Rev.Lett. 100:022303



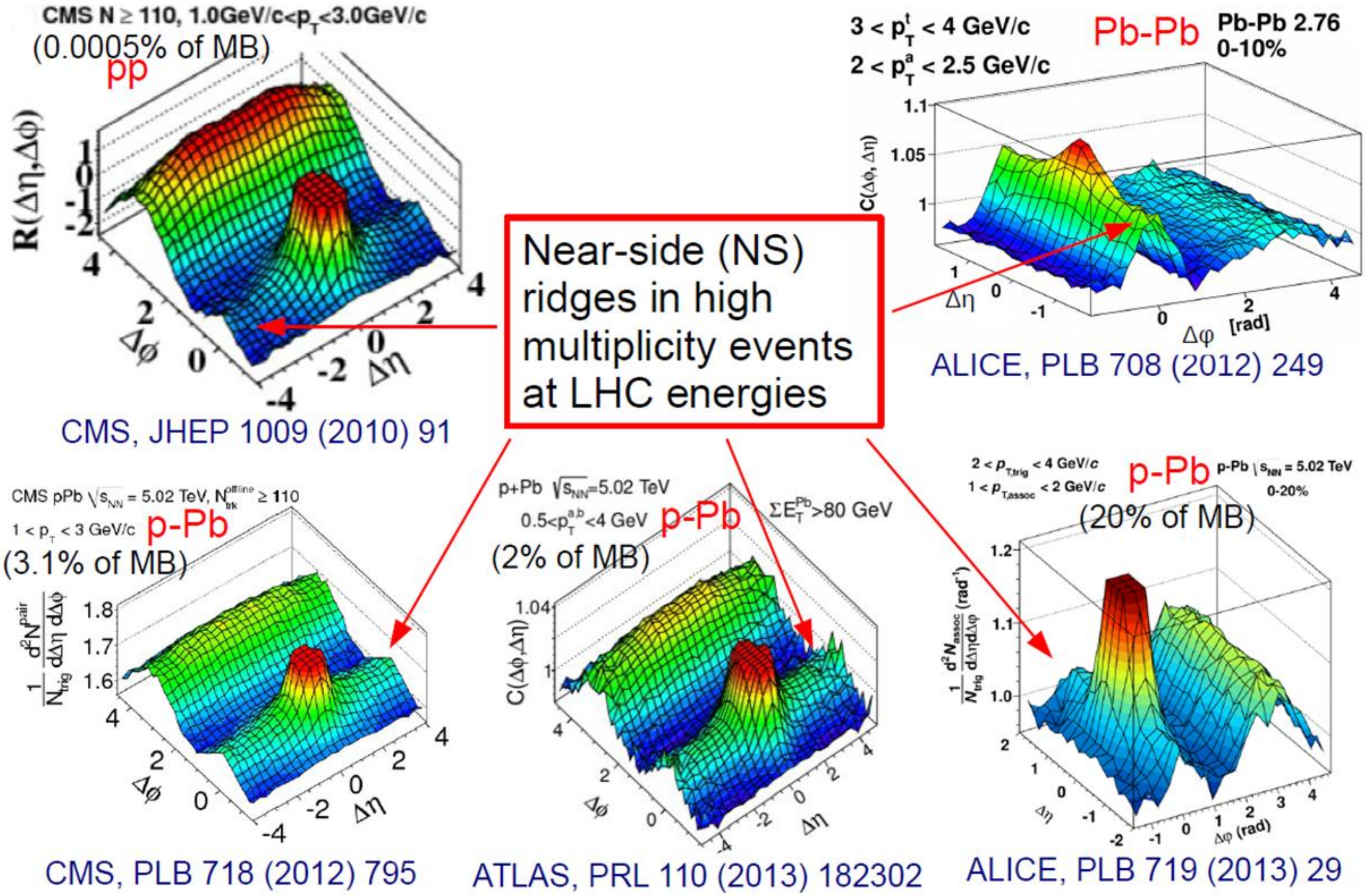
How much this lumpiness shows up in the data and what it tells us about viscosity was big story at QM2011

Углы импульсов частиц на LHC



Кинематические переменные частицы из зоны столкновения

Ридж- эффект в pp, pPb and PbPb



В Ридж были измерения от разностей $\Delta\eta = \eta_1 - \eta_2$, но не было измерений **корреляций для пар ($\eta^{\pm}_1$,$\eta^{\pm}_2$) с учётом заряда частиц**

(η_1,η_2) correlations

- Alternative observables: 2D correlation function

E. L. Berger, NPB 85 (1975) 61

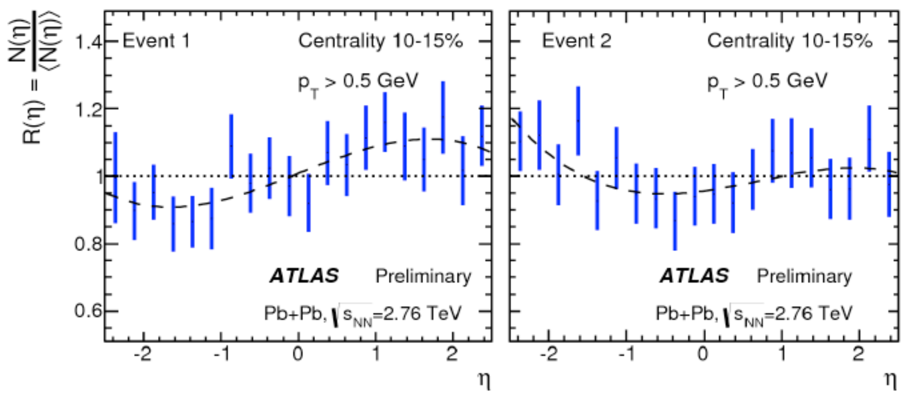
$$C=\frac{\langle N(\eta_1)N(\eta_2)\rangle}{\langle N(\eta_1)\rangle\langle N(\eta_2)\rangle}=\langle R_S(\eta_1)R_S(\eta_2)\rangle$$

$$\boxed{R_S(\eta)}\equiv\frac{N(\eta)}{\langle N(\eta)\rangle}$$

Single particle distribution

Mixed events may not match perfectly

FB asymmetry – асимметрия числа частиц по быстроте η, "вперед-назад"



Remove residual centrality dependence

$$C_N(\eta_1,\eta_2)=\frac{C(\eta_1,\eta_2)}{C_p(\eta_1)C_p(\eta_2)}$$

$$C_p(\eta_1)=\frac{\int C(\eta_1,\eta_2)d\eta_2}{2Y},\quad C_p(\eta_2)=\frac{\int C(\eta_1,\eta_2)d\eta_1}{2Y}$$

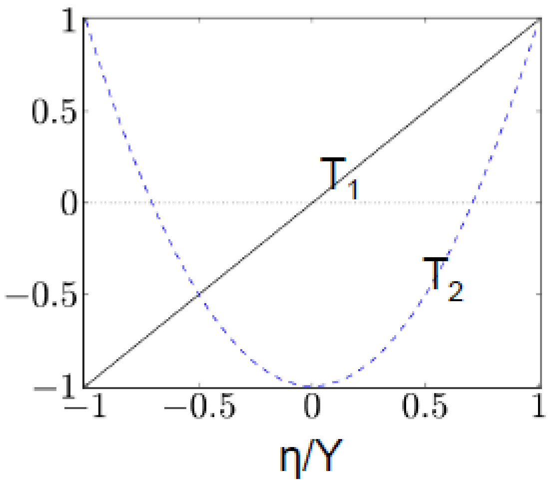
See 1506.03496 and talk by Peng Huo

$N(\eta)=dN/d\eta$ is the multiplicity density distribution in a single event and $\langle N(\eta\rangle$ is the average distribution for a given event-multiplicity class

Quantifying the shape fluctuations

- EbyE fluct. expanded in Legendre polynomials

See Bzdak, Teaney 1210.1965



$$R_S(\eta) \equiv \frac{N(\eta)}{\langle N(\eta)\rangle} = 1 + \sum_n a_n T_n(\eta) \quad T_n(\eta) \equiv \sqrt{\frac{2n+1}{3}}\, Y\, P_n\!\left(\frac{\eta}{Y}\right)$$

$$P_0(x) = 1, \quad P_1(x) = x, \quad P_2(x) = \frac{1}{2}(3x^2 - 1), \cdots$$

$$\boxed{\eta \in [-Y, Y], \quad Y = 2.4}$$

- a_1 → fluctuation in the FB asymmetry of N(η),
- a_2 → fluctuation in the width of N(η)

- Legendre expansion of two-particle correlations

$$C_N(\eta_1,\eta_2) = 1 + \sum_{n,m=1}^{\infty} \langle a_n a_m\rangle \frac{T_n(\eta_1)T_m(\eta_2) + T_n(\eta_2)T_m(\eta_1)}{2}$$

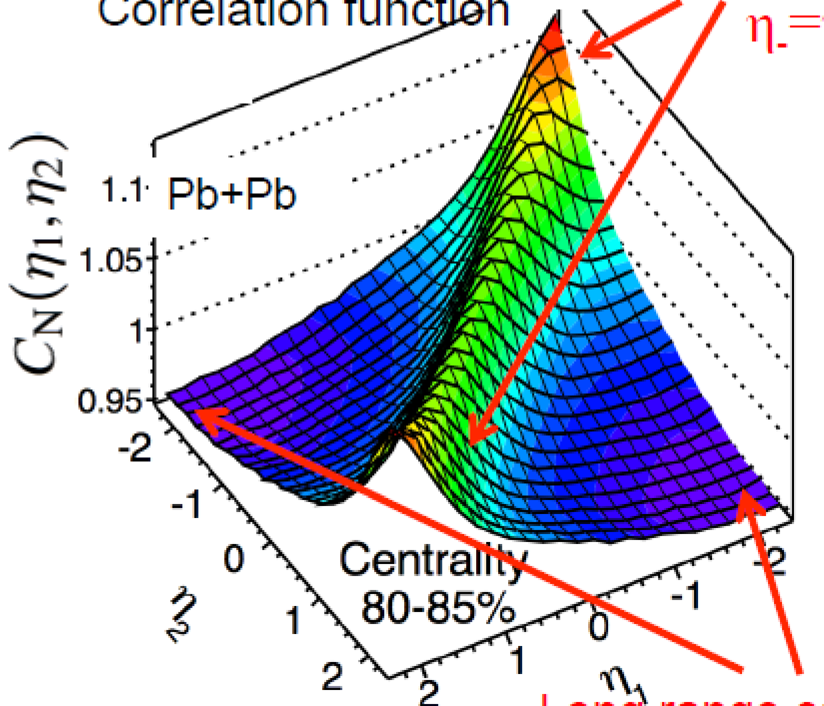
$$= 1 + \langle a_1^2\rangle \eta_1\eta_2 + \langle a_2^2\rangle \frac{5}{12Y^2}(3\eta_1^2 - Y^2)(3\eta_2^2 - Y^2) + \ldots$$

Features of $C_N(\eta_1,\eta_2)$

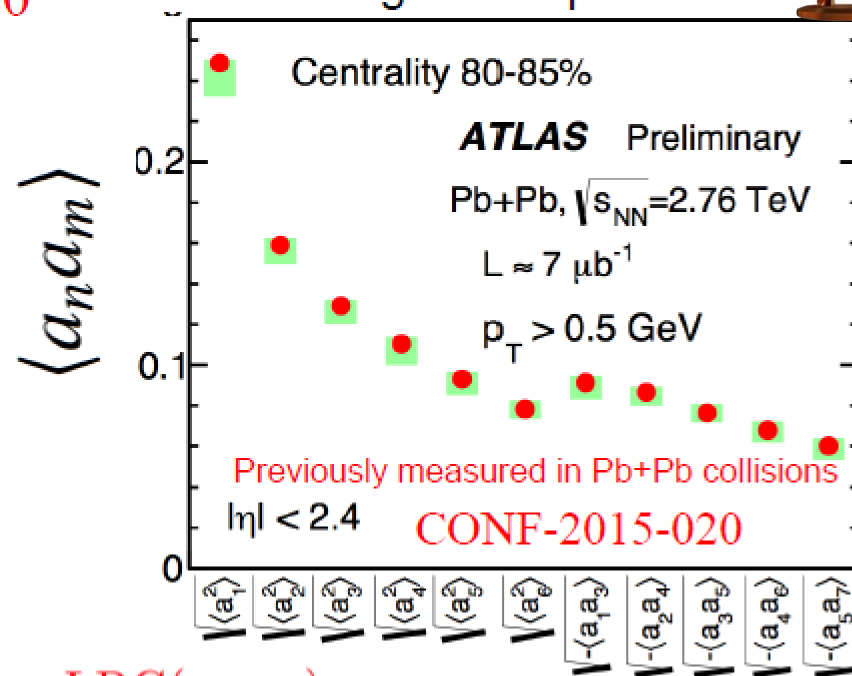
Short-range correlation $\delta_{\rm SRC}(\eta_1,\eta_2)$

$\eta_-=\eta_1-\eta_2\sim0$

Correlation function



Legendre spectra



$\eta_+=\eta_1+\eta_2$

$\eta_-=\eta_1-\eta_2$

Long range correlation $\mathrm{LRC}(\eta_1,\eta_2)$

$\eta_+=\eta_1+\eta_2\sim0$ & large $|\eta_-|$

- Corr. Func.=short-range corr. (SRC) + long-range corr. (LRC)

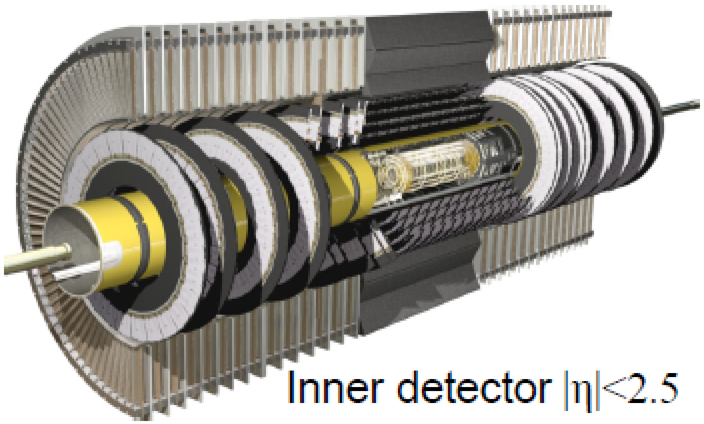
Goal of this measurement:

$$C(\eta_1,\eta_2)=1+\delta_{\rm SRC}(\eta_1,\eta_2)+\mathrm{LRC}(\eta_1,\eta_2)$$

1. Data-driven method to separate SRC from LRC
2. Compare SRC or LRC in three collision systems, pp,pPb,PbPb at similar N_{ch}

Pb+Pb, p+Pb and pp datasets

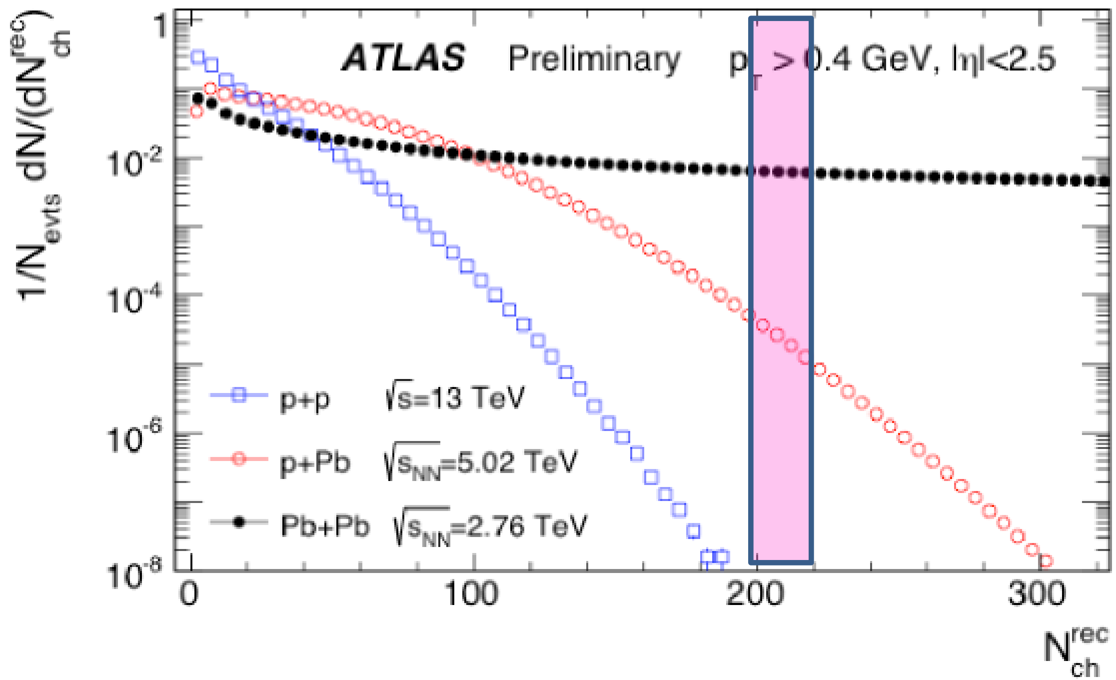
- $C_N(\eta_1,\eta_2)$ calculated using charged particles p_T>0.2 GeV.
- High-multiplicity track (HMT) trigger used to increase statistics



Pb+Pb 2.76 TeV, 2010, MB

p+Pb 5.02 TeV, 2013, MB+HMT

p+p 13 TeV, 2015, MB+HMT

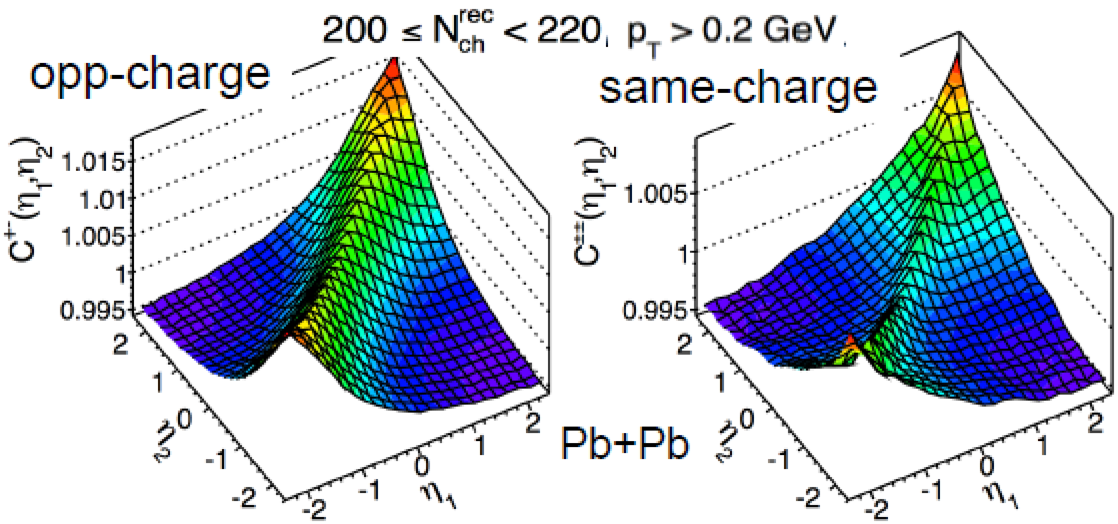


- Analysis carried out in many bins over $10 \leq N_{\mathrm{ch}}^{\mathrm{rec}} < 300$
- Results presented as a function efficiency-corrected values $N_{\mathrm{ch}} = bN_{\mathrm{ch}}^{\mathrm{rec}}$
  - b~1.19 for pp and ~1.29 for pPb and PbPb

How signals in three systems compare at same N_{ch}?

Properties of short-range correlations

- CF for +- and ++,-- pairs separately.
  - different SRC, similar LRC (based on ratio)



В коротко-действующих корреляциях (η1,η2) вклад пар с разными знаками зарядов (+,-) больше, чем с одинаковыми зарядами (++), (--)

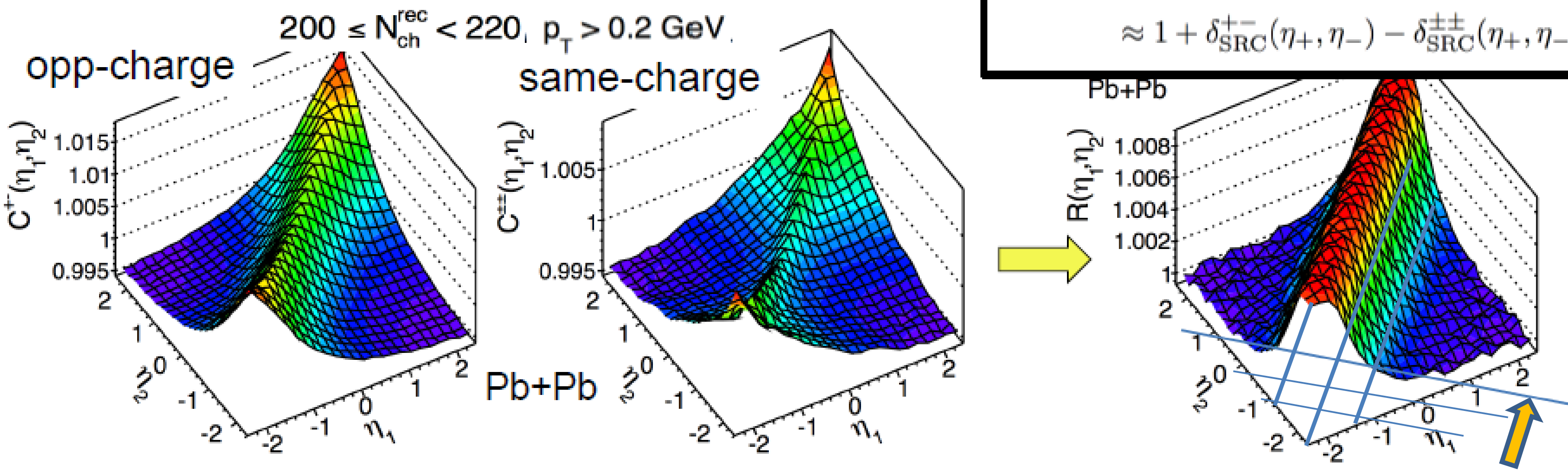
Properties of short-range correlations

- CF for +- and ++,-- pairs separately.
  - different SRC, similar LRC (based on ratio)

LRC drops out of the ratio

$$R(\eta_+,\eta_-) = \frac{C^{+-}(\eta_+,\eta_-)}{C^{\pm\pm}(\eta_+,\eta_-)} \qquad \begin{array}{l}\eta_+ = \eta_1+\eta_2 \\ \eta_- = \eta_1-\eta_2\end{array}$$

$$\approx 1 + \delta^{+-}_{\rm SRC}(\eta_+,\eta_-) - \delta^{\pm\pm}_{\rm SRC}(\eta_+,\eta_-)$$



more +- pairs than ±± pairs in each event more than 3 times for SRC

$\eta_+ = -2, \ldots 0, \ldots 2$

$\eta_+ = \eta_1 + \eta_2$
$\eta_- = \eta_1 - \eta_2$

Отношение корреляционных функций:

$$R(\eta_+,\eta_-) = \frac{C^{+-}}{C^{\pm\pm}} = 1 \quad \textit{при равном числе пар } (+-) \textit{ и } (\pm\pm)$$

$$R(\eta_+,\eta_-) = \frac{C^{+-}}{C^{\pm\pm}} = 1 + (\delta^{+-} - \delta^{\pm\pm}) \quad \textit{при неравном числе пар по знаку заряда}$$

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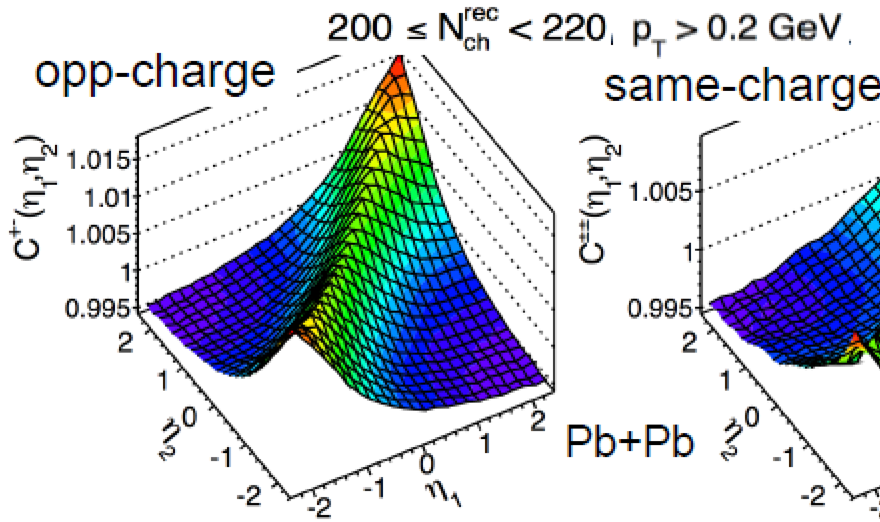
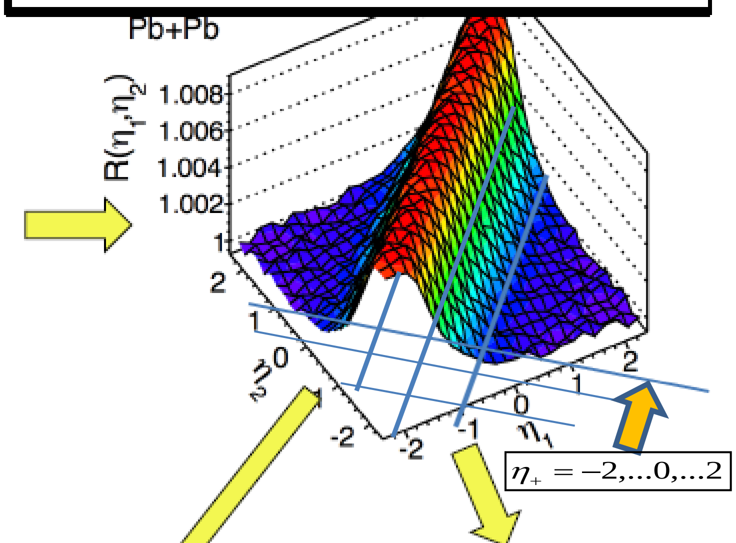
$$R(\eta_+,\eta_-) = \frac{C^{+-}(\eta_+,\eta_-)}{C^{\pm\pm}(\eta_+,\eta_-)} \qquad \eta_+ = \eta_1+\eta_2,\quad \eta_- = \eta_1-\eta_2$$

$$\approx 1 + \delta^{+-}_{\mathrm{SRC}}(\eta_+,\eta_-) - \delta^{\pm\pm}_{\mathrm{SRC}}(\eta_+,\eta_-)$$





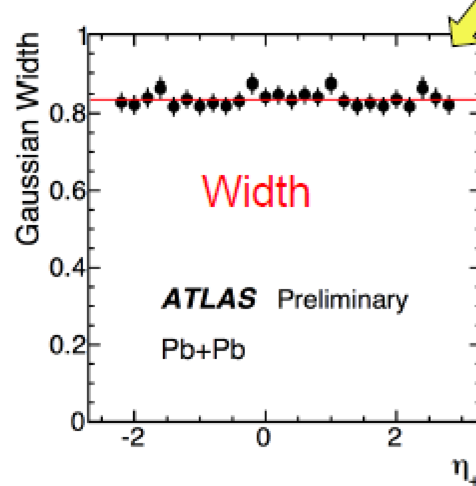
- Amplitude quantified via

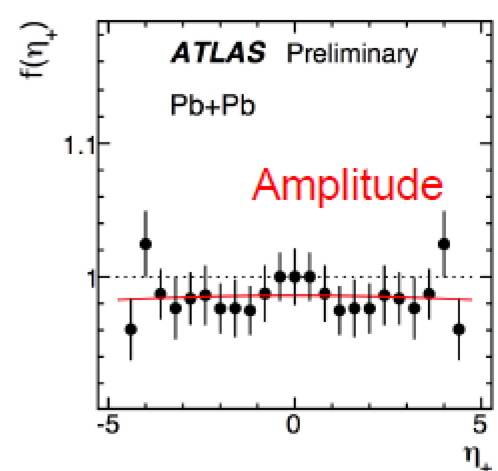
$$f(\eta_+) = \frac{\int_{-0.4}^{0.4} R(\eta_+,\eta_-)/0.8\, d\eta_- - 1}{\int_{-0.4}^{0.4} R(0,\eta_-)/0.8\, d\eta_- - 1}$$

Shape along η_+

- η_- peak width is constant in η_+

Shape of $\delta^{+-}_{\mathrm{SRC}} - \delta^{\pm\pm}_{\mathrm{SRC}}$ factorize in η_+ and η_-





Properties of short-range correlations

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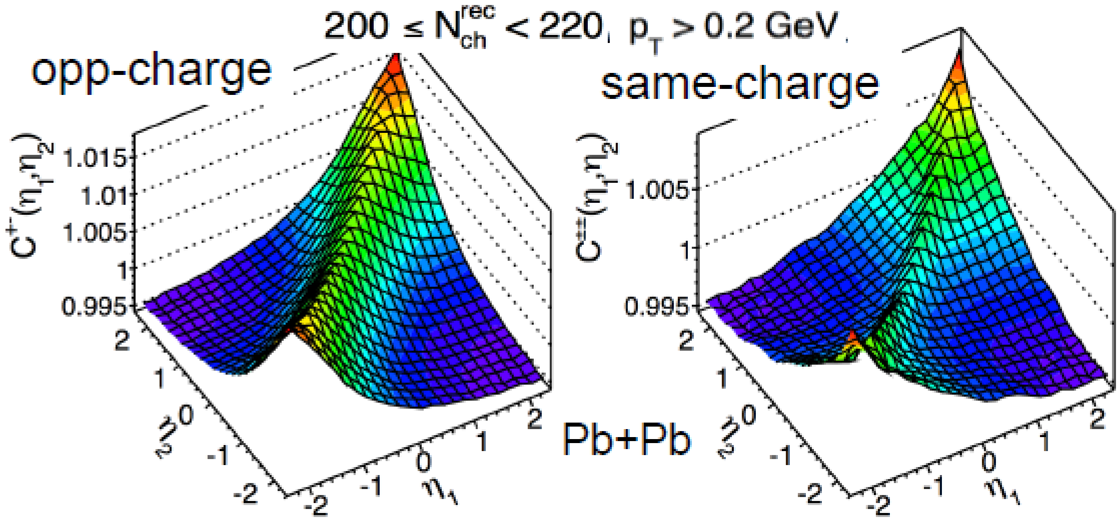
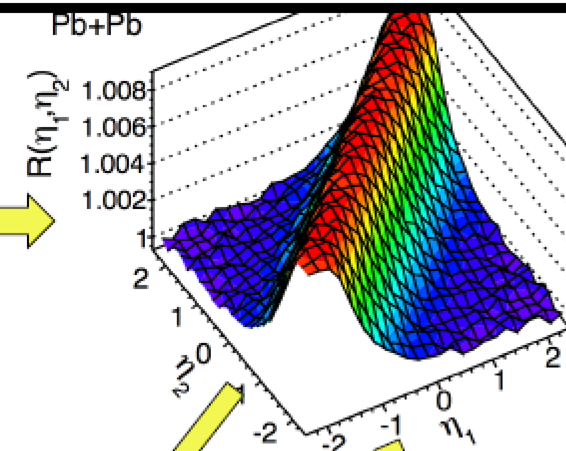
LRC drops out of the ratio

$$R(\eta_+,\eta_-) = \frac{C^{+-}(\eta_+,\eta_-)}{C^{\pm\pm}(\eta_+,\eta_-)} \qquad \begin{aligned}\eta_+ &= \eta_1+\eta_2 \\ \eta_- &= \eta_1-\eta_2\end{aligned}$$

$$\approx 1 + \delta^{+-}_{\rm SRC}(\eta_+,\eta_-) - \delta^{\pm\pm}_{\rm SRC}(\eta_+,\eta_-)$$





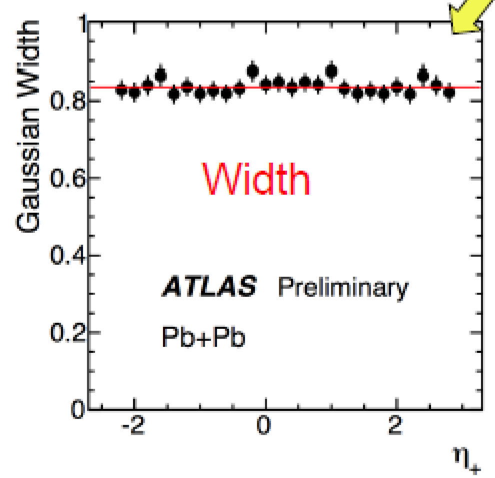
Hence, $\delta_{SRC}(\eta_+,\eta_-)$ assumed to factorize in η_+,η_-.

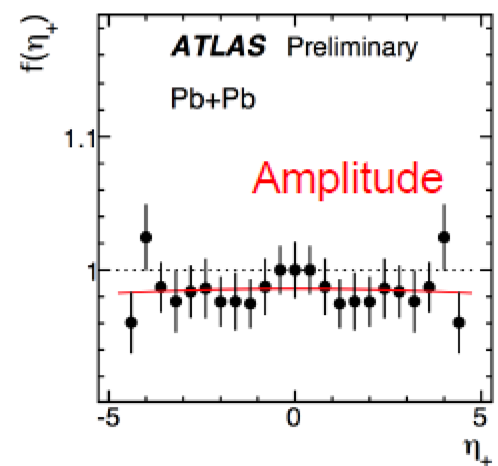
$$\delta^{+-}_{\rm SRC} = f(\eta_+)g^{+-}(\eta_-)$$

$$\delta^{\pm\pm}_{\rm SRC} = f(\eta_+)g^{\pm\pm}(\eta_-)$$

$$R(\eta_+,\eta_-) \approx 1 + f(\eta_+)\left[g^{+-}(\eta_-) - g^{\pm\pm}(\eta_-)\right]$$

Key is to determine $g(\eta_-)$!



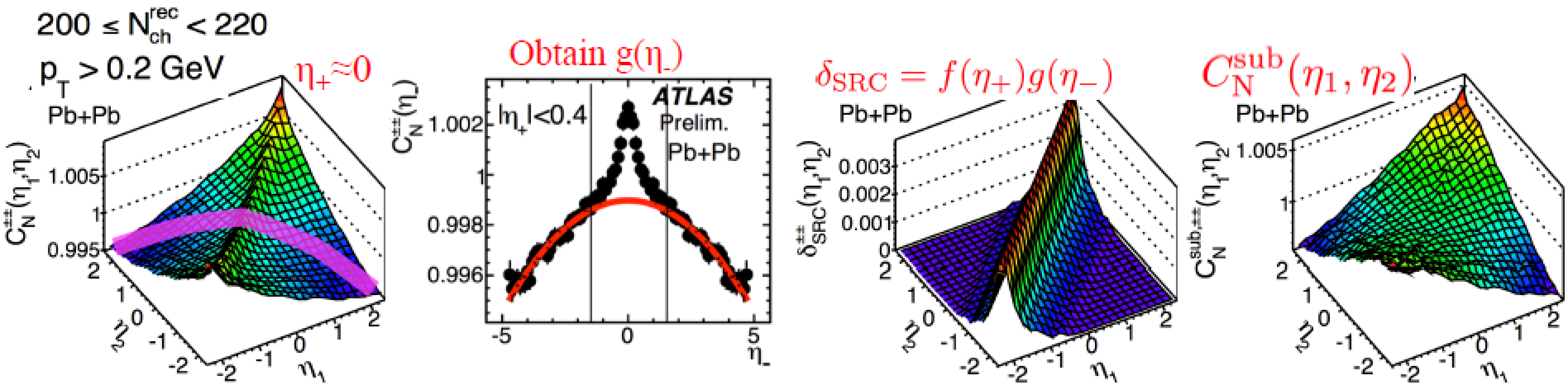


Estimate short-range correlations

- Take $C_N(\eta_-)$ in $|\eta_+|<0.4$, fit a quadratic function in $|\eta_-|>\eta_0=1.5$, difference between data and fit in $|\eta_-|<2$ is the $g(\eta_-)$ for SRC
  - Vary η_0 and the range of η_+ slices to check systematics.

$$\delta^{+-}_{\mathrm{SRC}} = f(\eta_+)g^{+-}(\eta_-)$$

$$\delta^{\pm\pm}_{\mathrm{SRC}} = f(\eta_+)g^{\pm\pm}(\eta_-)$$



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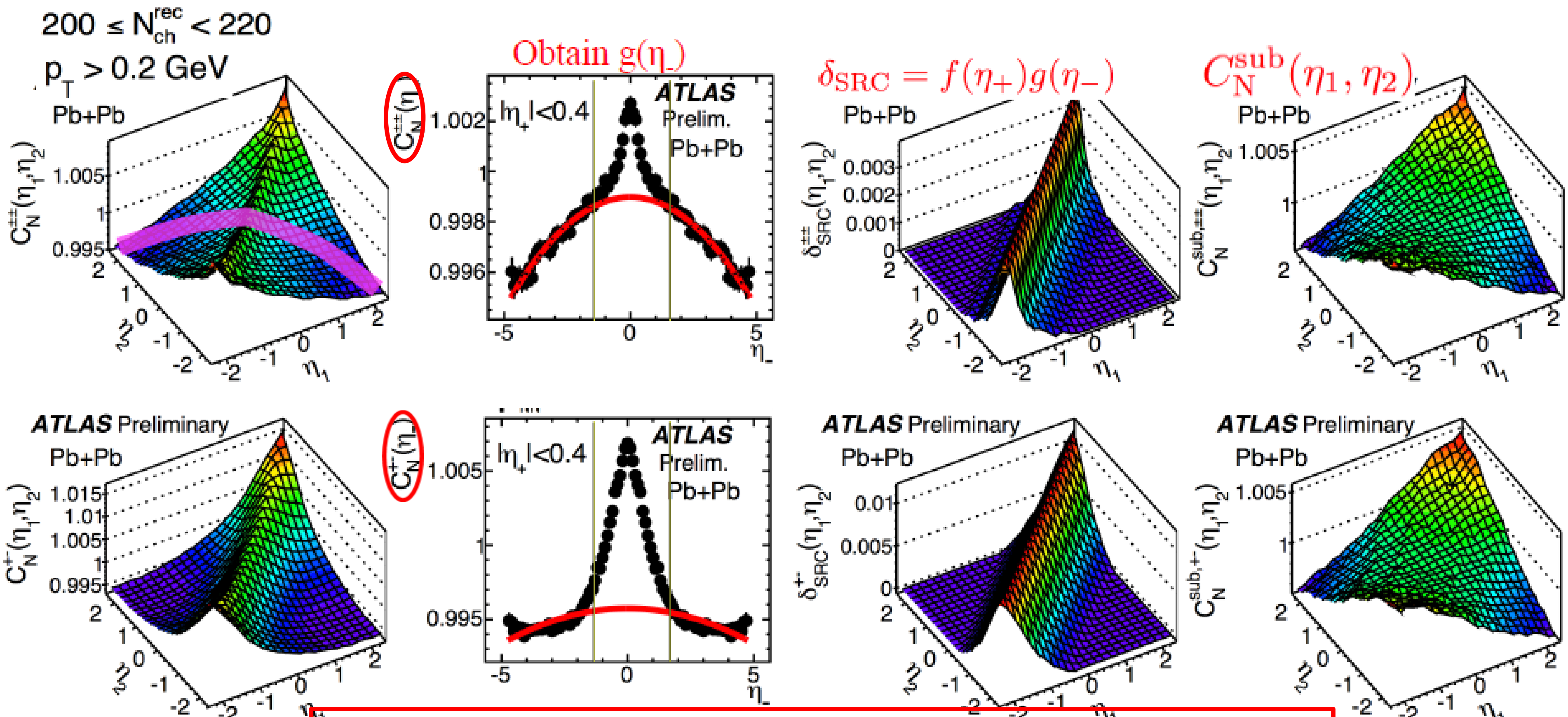
  - Vary η_0 and the range of η_+ slices to check systematics.

$$\delta_{\rm SRC}^{+-} = f(\eta_+)g^{+-}(\eta_-)$$
$$\delta_{\rm SRC}^{\pm\pm} = f(\eta_+)g^{\pm\pm}(\eta_-)$$



The SRC more +– pairs than ±± pairs in each event by factor 3

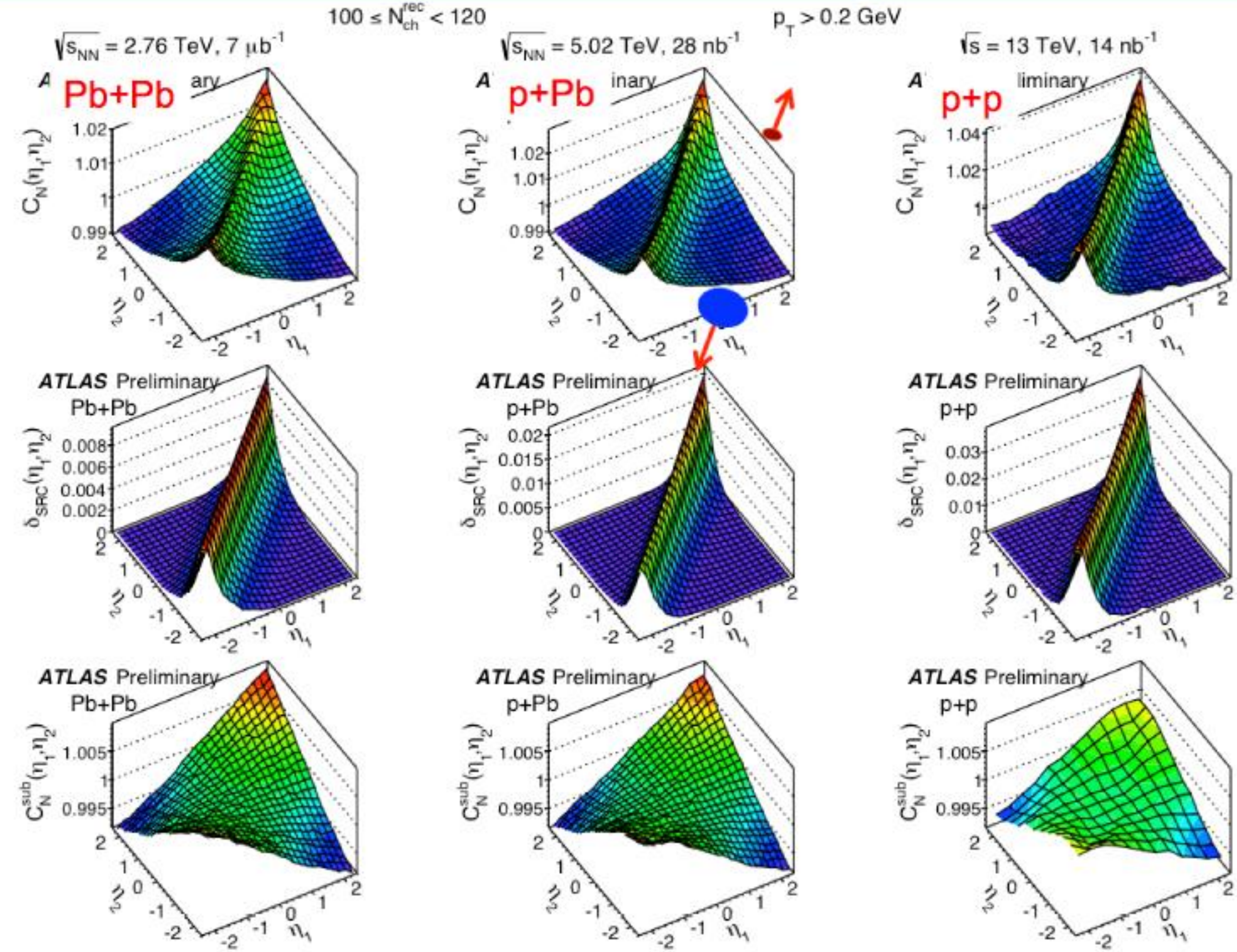
The LRC, $C_N^{\rm sub}(\eta_+,\eta_-)$, has similar magnitudes between ++,-- and +-

Correlation functions in three systems

$C_{\mathrm{N}}(\eta_1,\eta_2)$

Short-range $\delta_{\mathrm{SRC}}(\eta_1,\eta_2)$

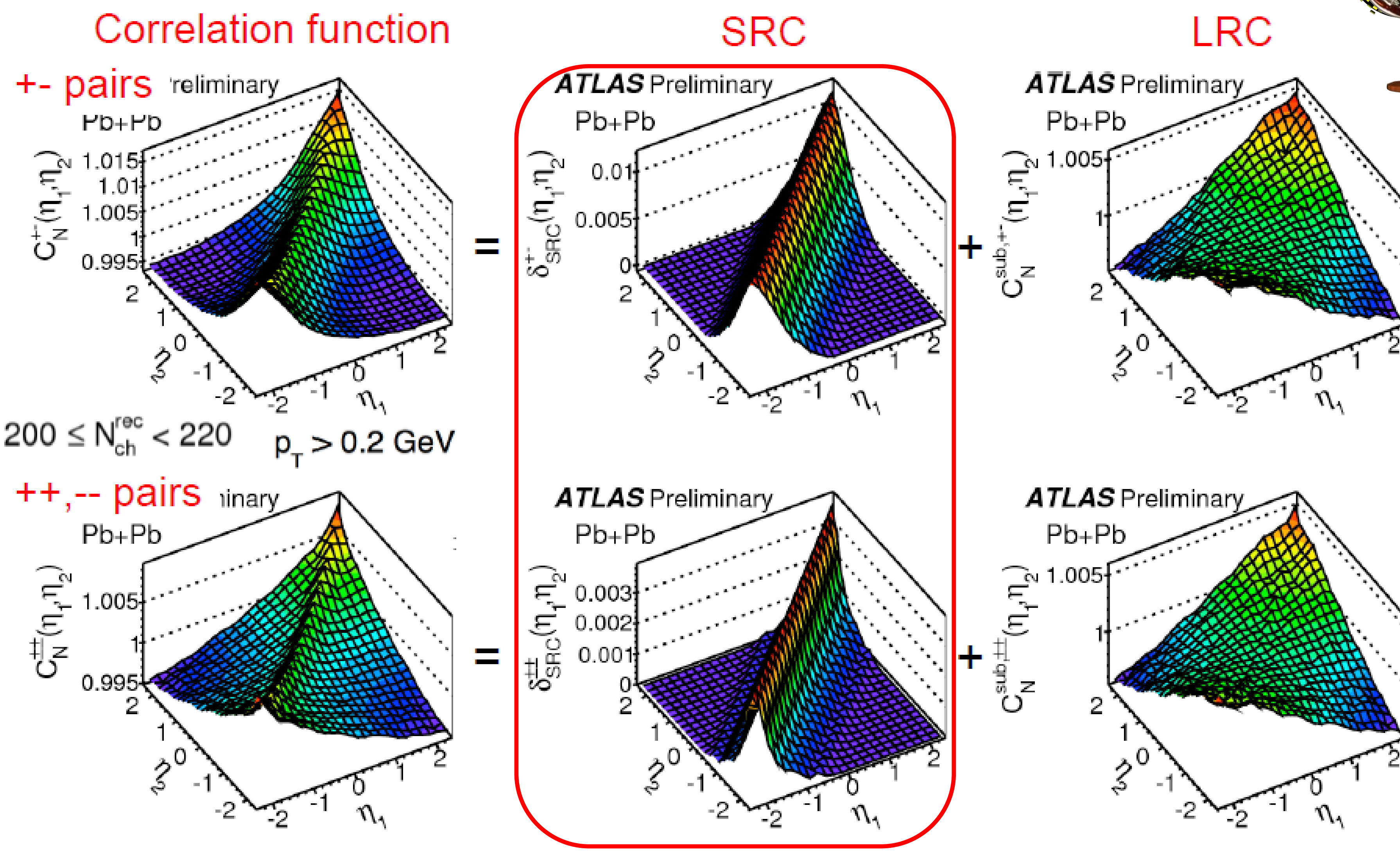
Long-range $C_{\mathrm{N}}^{\mathrm{sub}}(\eta_1,\eta_2)$



After SRC subtraction, similar LRC in all three systems

Most FB asymmetry in pPb collisions is due to the SRC.

Dependence on charge combination



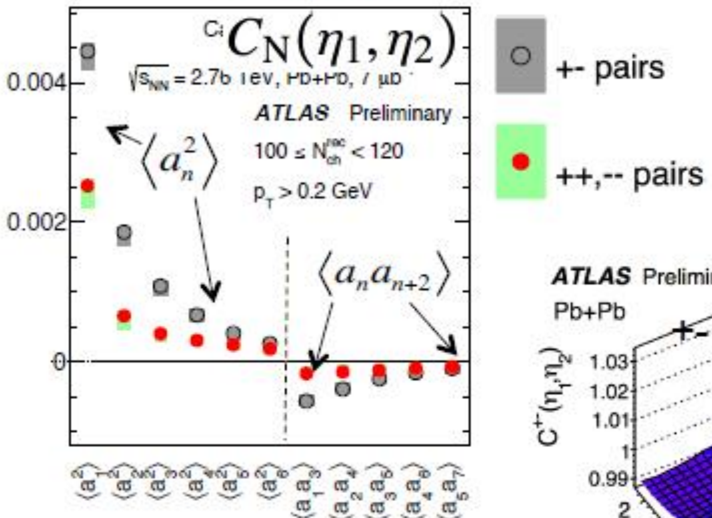
- SRC: more +- pairs than ±± pairs in each source
- LRC: no charge dependence → reflect global event property

Legendre spectra in Pb+Pb

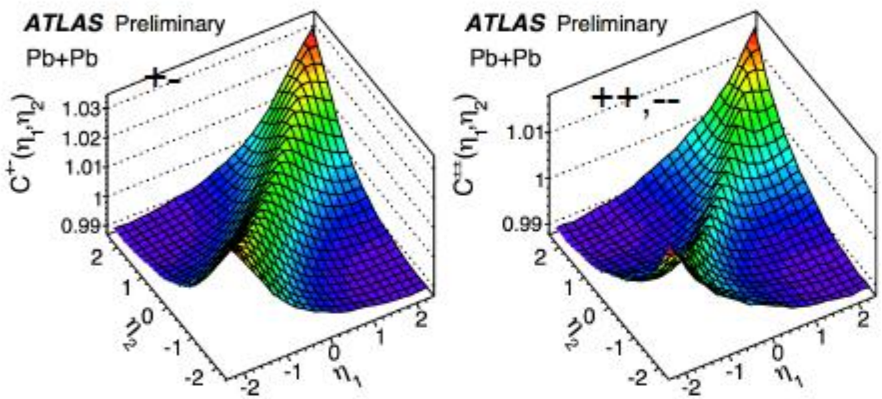
$$C_N(\eta_1,\eta_2) \text{ or } C_N^{sub}(\eta_1,\eta_2) = 1 + \sum_{n,m=1}^{\infty} \langle a_n a_m \rangle \frac{T_n(\eta_1)T_m(\eta_2) + T_n(\eta_2)T_m(\eta_1)}{2}$$

Pb+Pb

Before subtraction



Before SRC subtraction



- The strong charge dependence → SRC contributes to all coefficients

Legendre spectra in Pb+Pb

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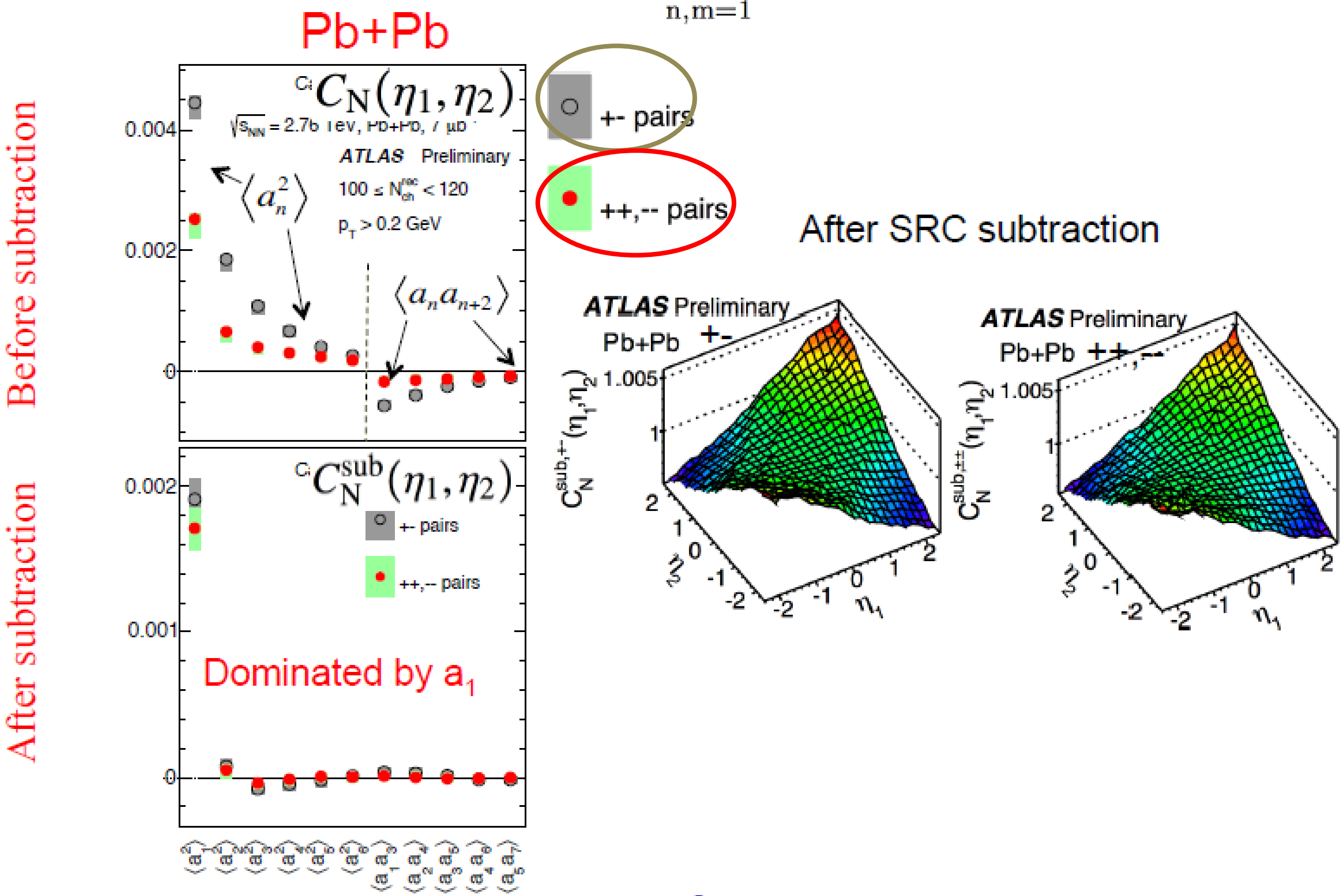

- The strong charge dependence → SRC contributes to all coefficients

After SRC removal, results are independent of charge combinations!

Legendre spectra in three systems

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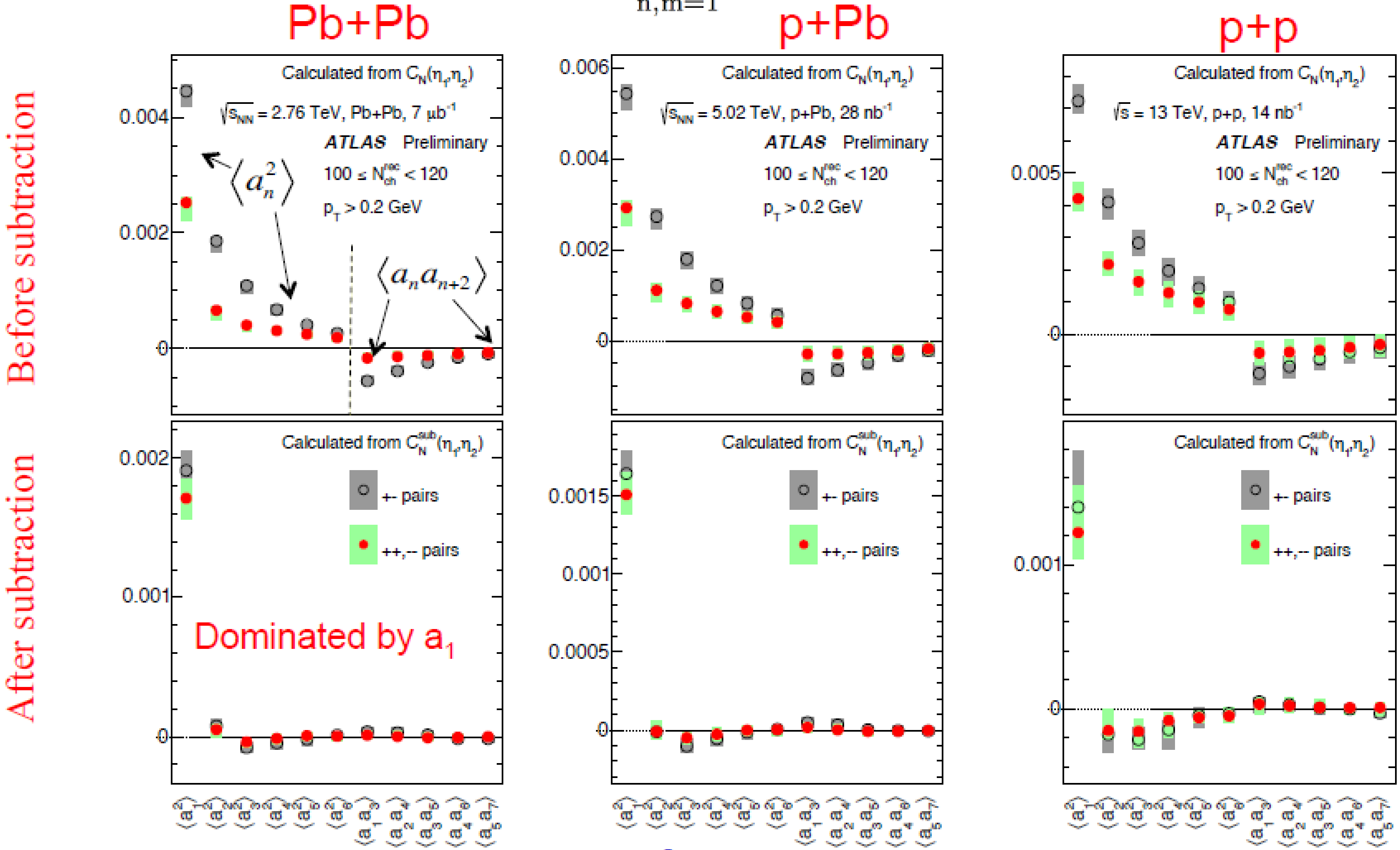


- The strong charge dependence → SRC contributes to all coefficients

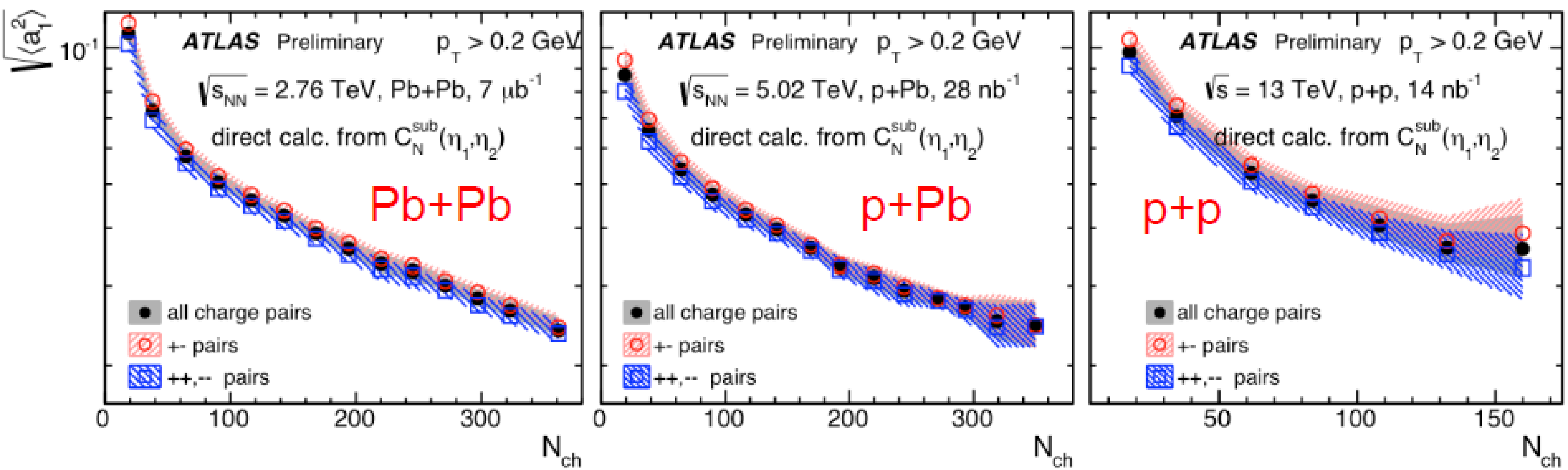
After SRC removal, results are independent of charge combinations!

N_{ch} dependence of LRC (in terms of a_1)

$$C_N^{\mathrm{sub}}(\eta_1,\eta_2) \approx 1 + \left\langle a_1^2 \right\rangle \eta_1\eta_2$$

доминирует !

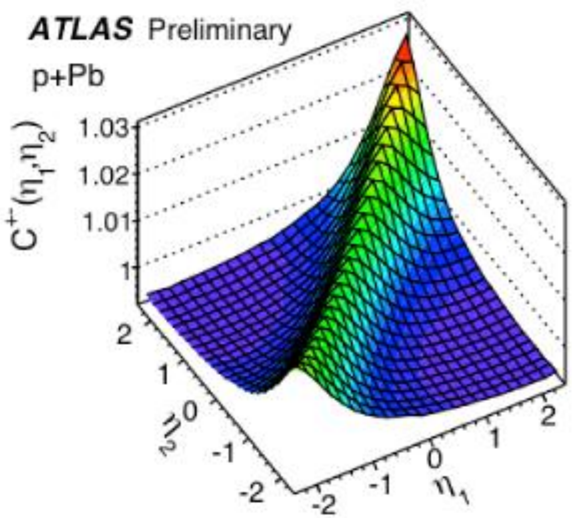
- Calculated from Legendre expansion method for all-charge, opposite-charge and all-charge pairs

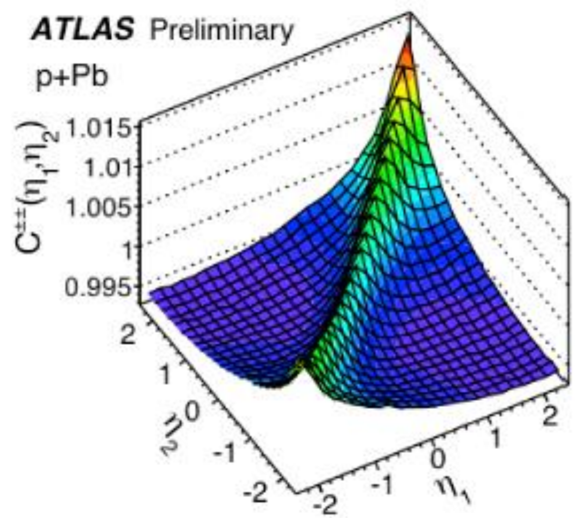


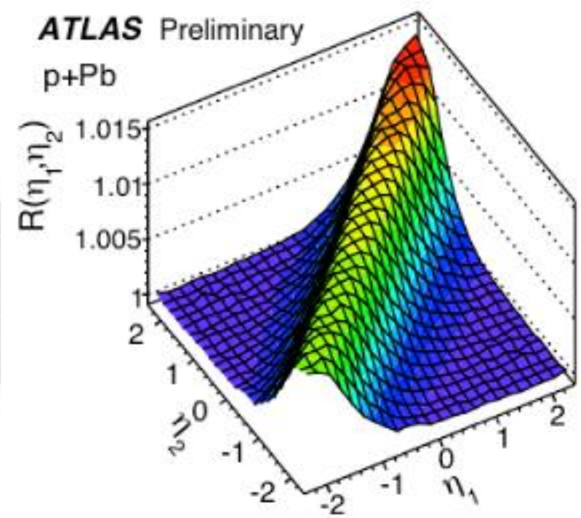
No dependence on charge combinations

Properties of SRC in p+Pb

- Most of the FB asymmetry is in the magnitude of the SRC.
- η_--width of SRC is constant as a function of η_+.





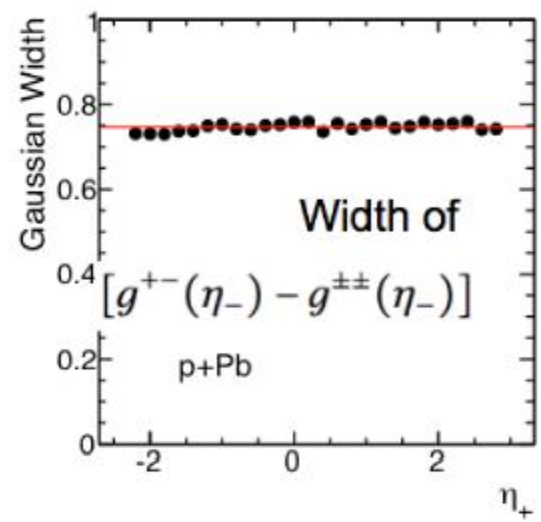


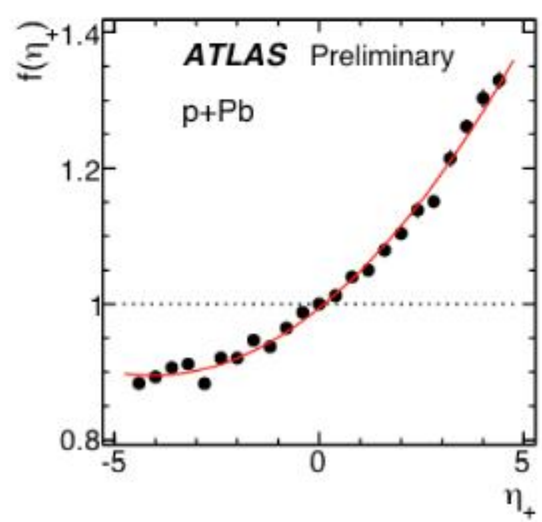
ATLAS Preliminary

$200 \leq N_{ch}^{rec} < 220$

$\sqrt{s_{NN}}$ = 5.02 TeV, p+Pb, 28 nb^{-1}

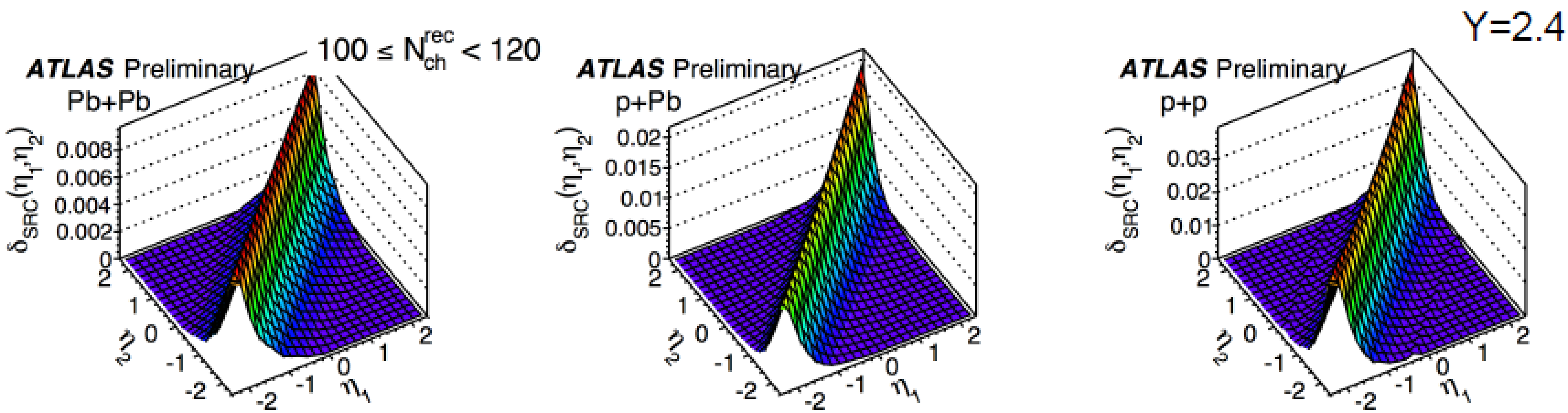
$p_T > 0.2$ GeV





N_{ch} dependence of SRC

- Quantify SRC using its average amplitude $\Delta_{SRC} = \frac{\int \delta_{SRC}(\eta_1,\eta_2)d\eta_1 d\eta_2}{4Y^2}$



N_{ch} dependence of SRC

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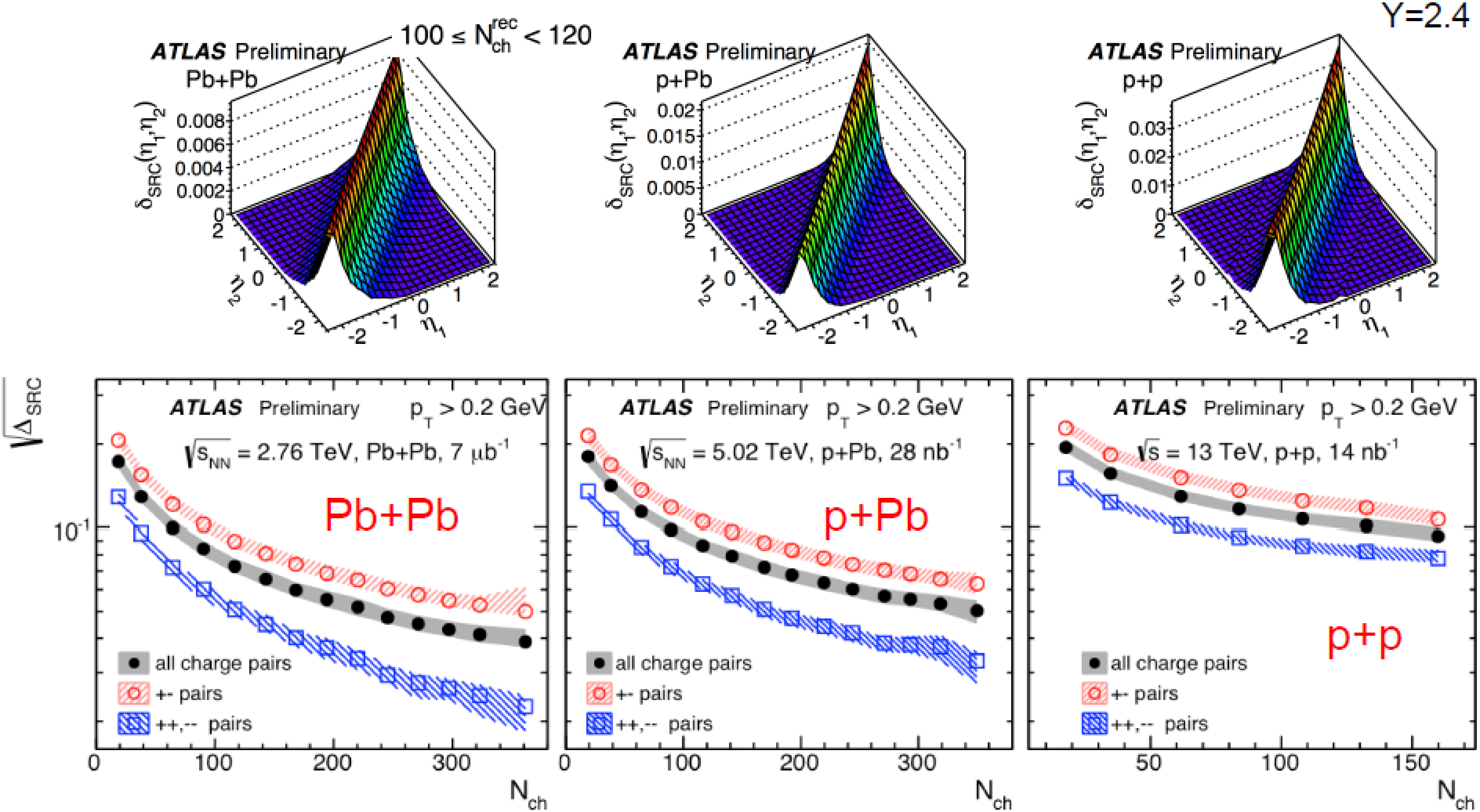
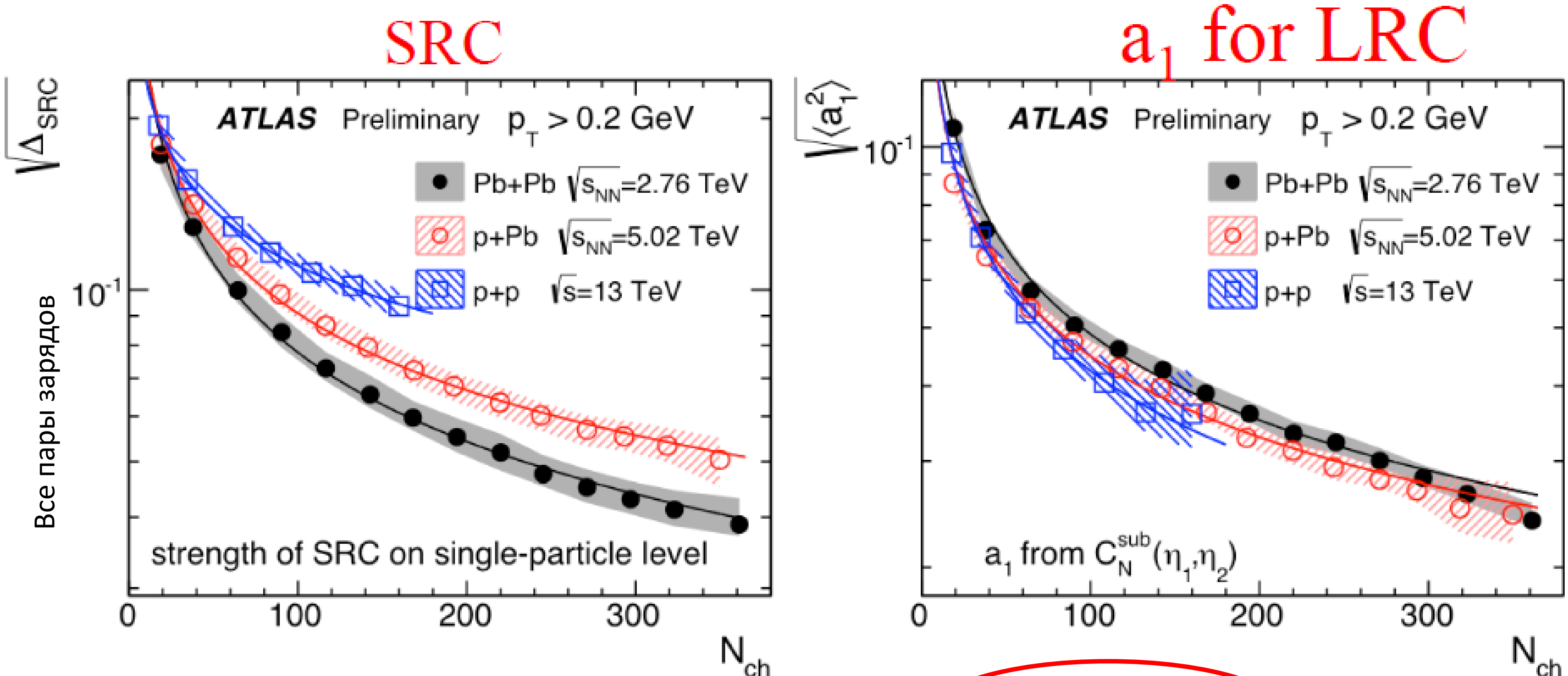
Y=2.4



Strong dependence on charge and system size

N_{ch} dep. of SRC and a_1 in three systems



- They follow power-law function

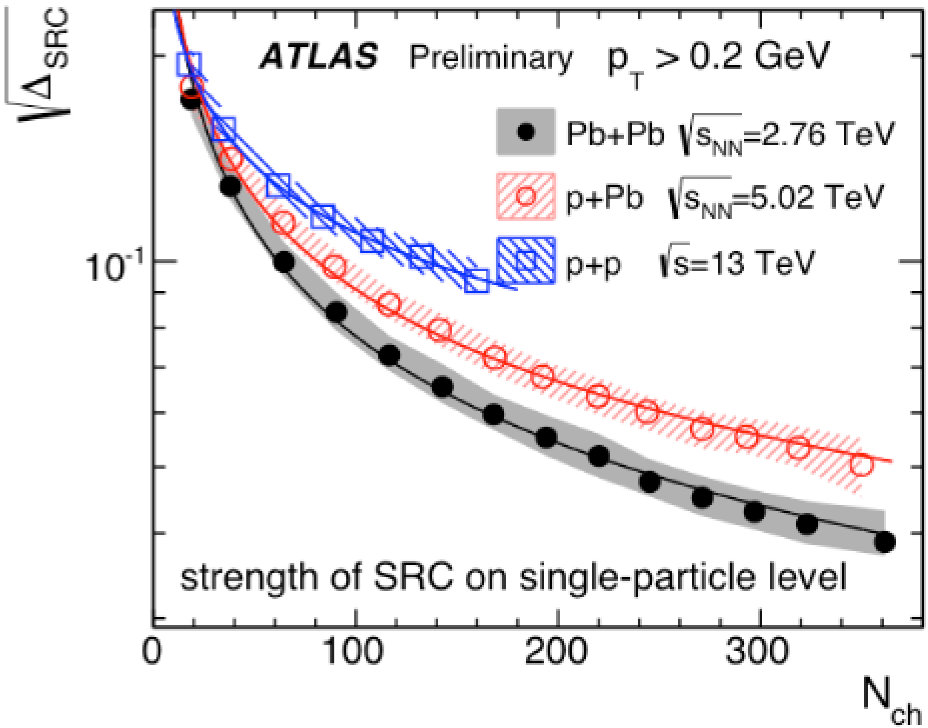
Fit with c/N_{ch}^{α}

	Pb+Pb	p+Pb	pp
α for $\sqrt{\Delta_{SRC}}$	0.502 ± 0.022	0.451 ± 0.020	0.342 ± 0.030
α for $\sqrt{\langle a_1^2 \rangle}$	0.467 ± 0.011	0.448 ± 0.019	0.489 ± 0.032

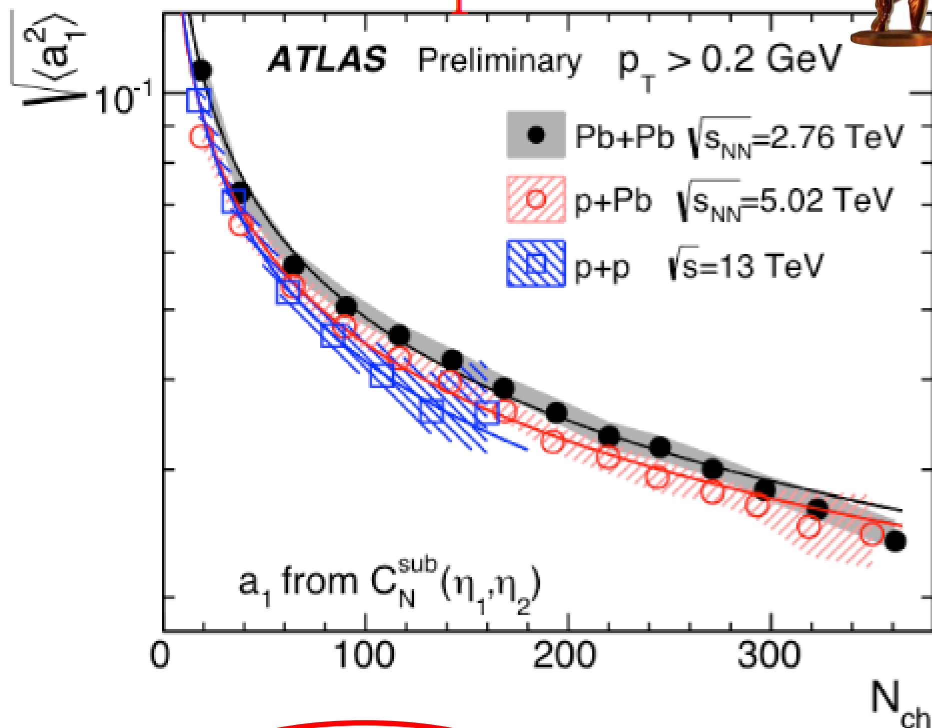
- LRC: num. of sources, n, controlled by N_{ch}, think in terms of partons !
- SRC: pp vs PbPb at same $N_{ch} \rightarrow$ n is similar but pairs/source is larger?

N_{ch} dep. of SRC and a_1 in three systems

SRC



a_1 for LRC



- They follow power-law function   Fit with c/N_{ch}^{α}

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α smaller in pp→ num. of cluster is smaller or cluster size is larger at same N_{ch}?

Expected scaling behavior?

- SRC can be related to the number of sources n contributing to N_{ch}

$$n = n_f + n_b \propto N_{\mathrm{ch}}$$

- LRC expected to be related to the asymmetry between n_f and n_b

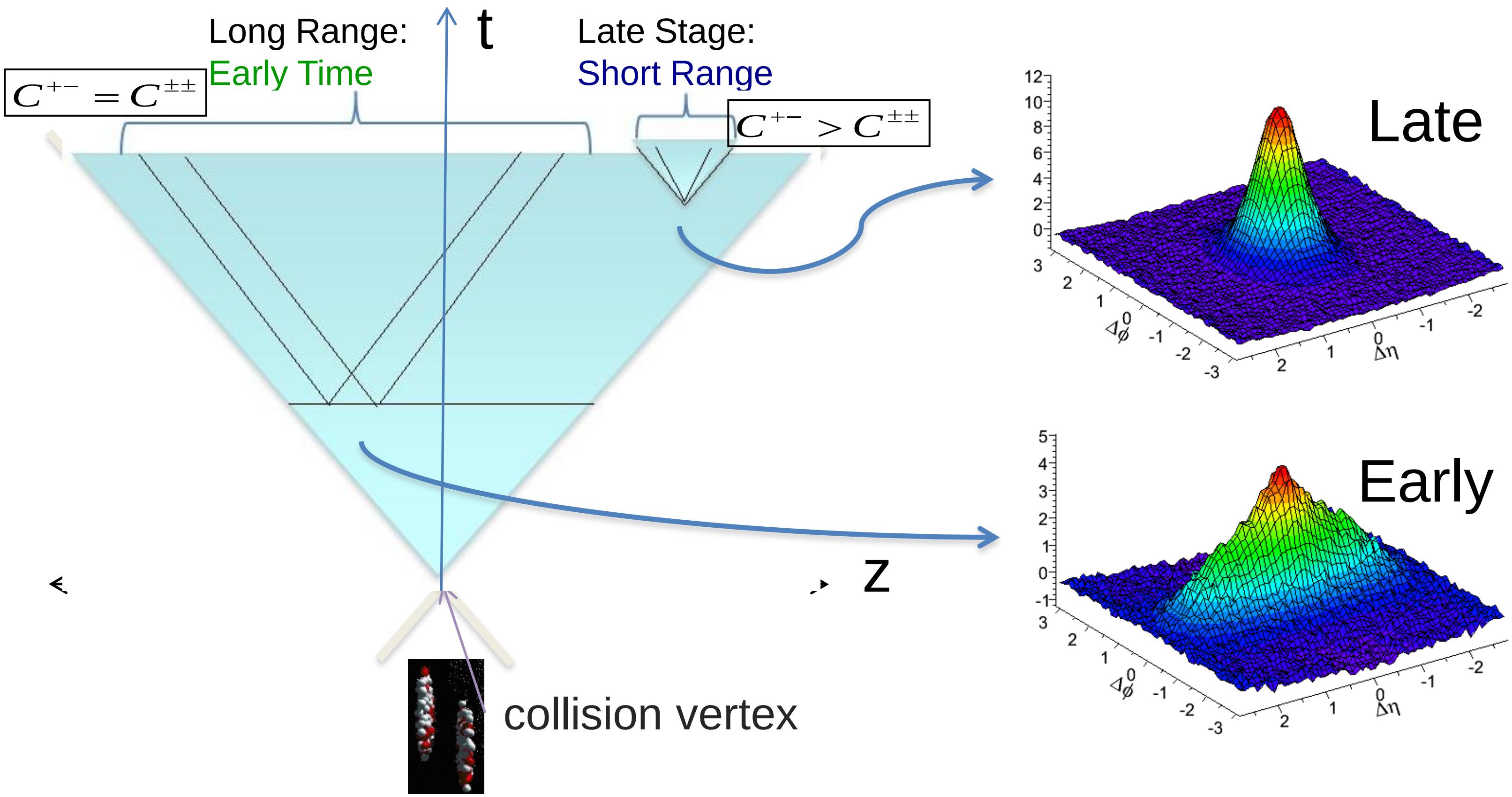
$$A_n = \frac{n_f - n_b}{n_f + n_b}, \quad \langle a_1^2 \rangle \propto \langle A_n^2 \rangle$$

- Assume independent cluster picture NPB85 (1975)61: each source emits the same number of pairs and the number of sources follows Poisson fluctuations, then

$$\sqrt{\Delta_{\mathrm{SRC}}} \sim \sqrt{\langle a_1^2 \rangle} \sim \frac{1}{n^\alpha} \sim \frac{1}{N_{\mathrm{ch}}^\alpha}, \alpha \sim 0.5$$

Sources could be:
wounded nucleons, or partons (via frag.), flux tubes, or final state resonance decays

Correlations from Initial State



The longitudinal width of the correlation is *related to the time the correlation was established*★

late stage correlation will be narrow in Δη, early times wide

Sorensen, QM2012

★Dumitru, Gelis, Venugopalan, McLerran: Nucl. Phys.A 810:91,2008

Быстротные (η_1,η_2) корреляции

Conclusion on ATLAS work **J.Jia QM2015**

1. Впервые измерены и проанализированы равно- и противоположно заряженные 2-х частичные η_1-η_2 корреляции в PbPb столкновениях.

2. Разделены коротко-действующие SRC и длинно-действующие LRC корреляции. SRC имеют больше + – пар, меньше + +, + – пар, LRC имеют таких пар одинаковое количество.

3. Показано, что после вычитания SRC функция корреляции $C^{sub}(\eta_1,\eta_2)$ одинакова для всех трёх систем pp, pPb, PbPb

4. Предполагается кластерная природа источников E. L. Berger NPB85 (1975)61: каждый источник испускает примерно равное число частиц, а число источников соответствует Пуассоновскрму распреледению

Спасибо за внимание

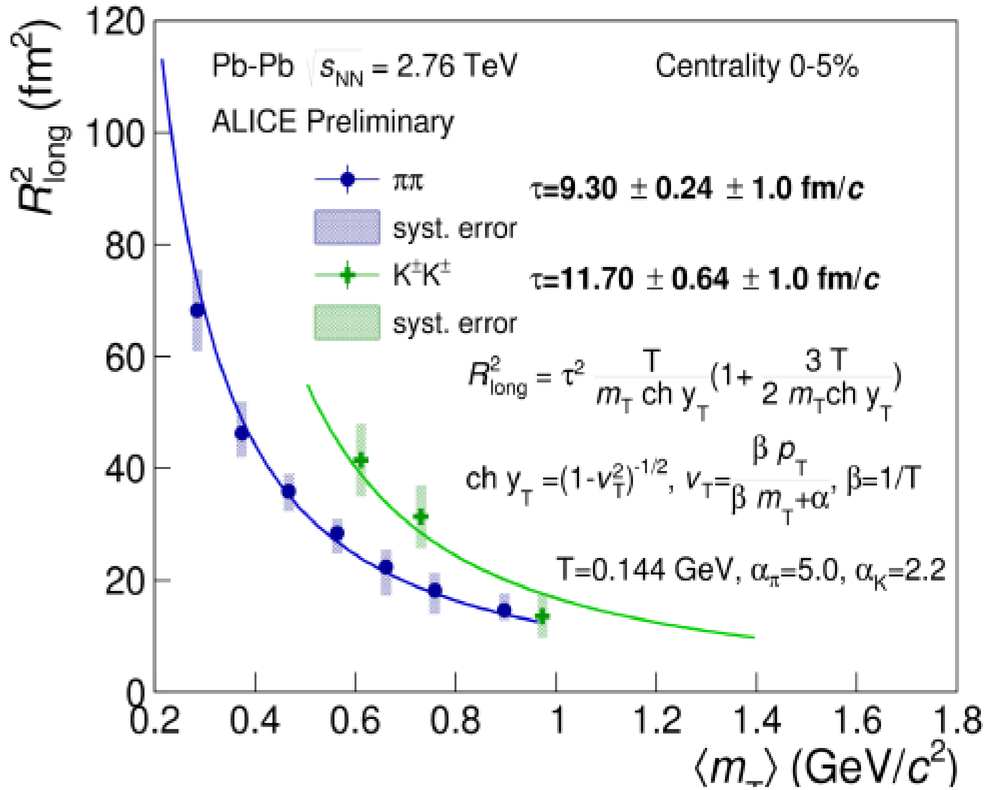
Далее прошу рассмотреть мои предложения
для докладов некоторых сотрудников
на лабораторном семинаре

Возможные доклады сотрудников

Далее мои рекомендации – предложения (можно также выбрать самостоятельно из QM2015) некоторым сотрудникам, работающим в соответствующих направлениях.

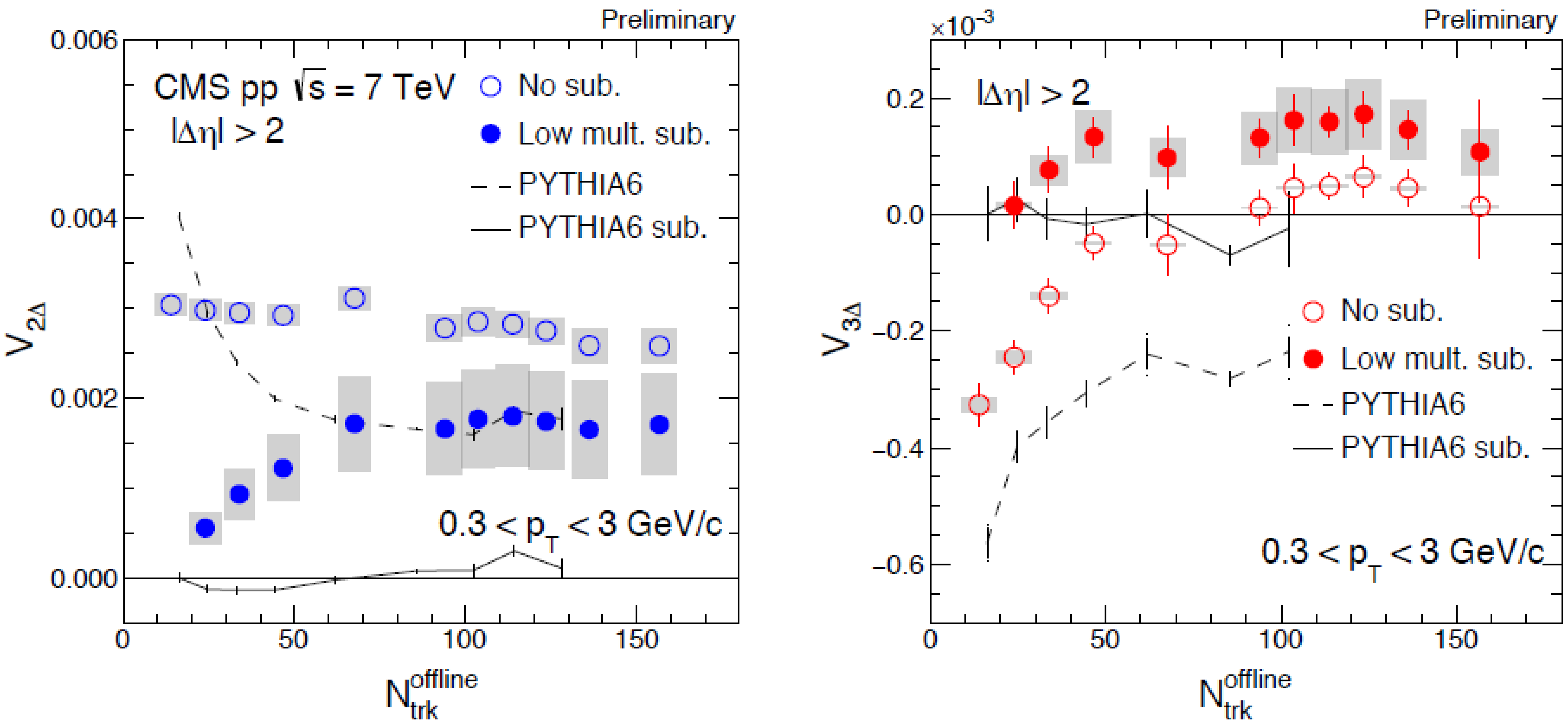
Л.В. Малинина « ALICE и FAIR-NICA после QM2015» (название условное, Л.В. предложит своё, QM15 Femtoscopy of identified particles in Pb-Pb collisions with ALICE at the LHC)

Настоящее исследование показало необходимость учёта перерассеяний и как следствие нарушение m_T scaling-а с разными максимальными временами испускания пионов и каонов (9.3 и 11.7 фм/с).



Г.Х. Эйюбова «Гармоники длинно действующих корреляций в pp столкновениях» (на основе доклада Zhenyu Chen «Anisotropy harmonics from long-range correletions in high multiplicity pp collisions» QM15_Zhenyu_v6_Vn_high_multi.pdf)

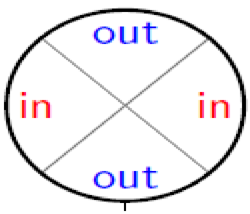
Полное и детальное исследование анизотропных гармоник в **pp** столкновениях, включая идентификацию частиц, Double Ridge в pp. Не плохо бы сравнить с нашим исследованием по V2 в pp столкновениях в статье с D. D'Enterria



- $V_{2\Delta}$, $V_{3\Delta}$ become relative constant at high multiplicity

С.В. Петрушанко «Разный выход струй в зависимости от угла плоскости события» (на основе доклада R.Bertens «Azimuthal anisotropy of R = 0.2 charged jet production in 2.76 TeV Pb-Pb collisions», rbertens_QM2015_v3.pdf + arXiv:1509.07334)

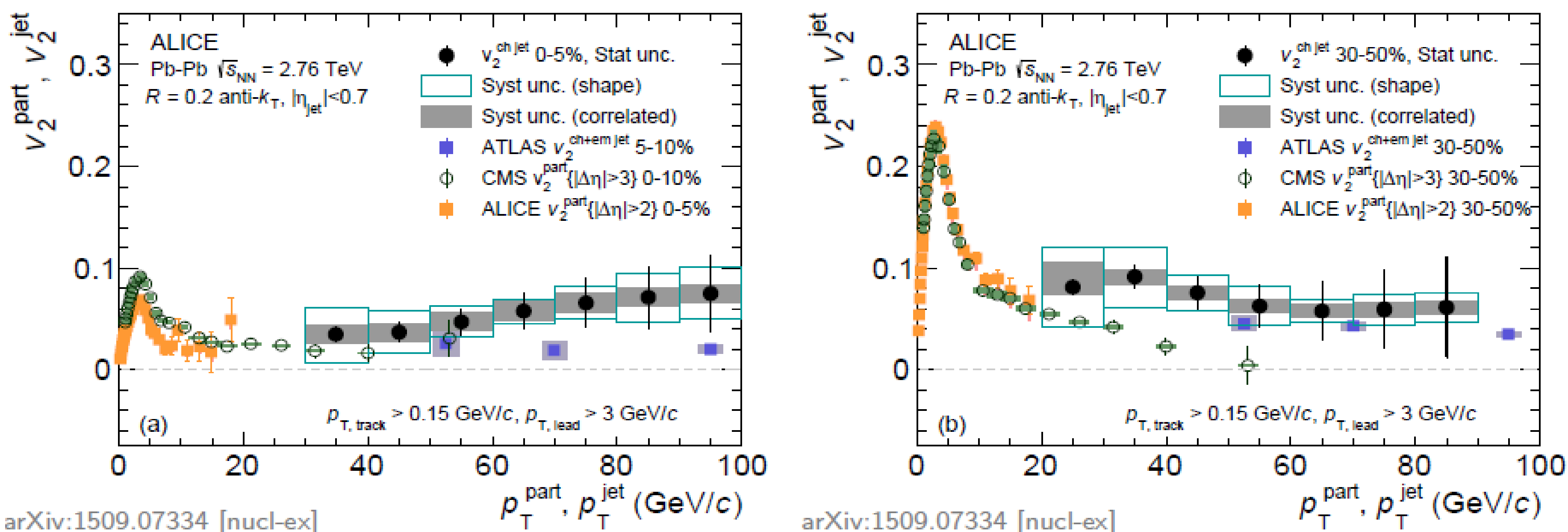
Работа интересна тем, что впервые доказан экспериментально **разный** выход струй в зависимости от угла плоскости реакции для второй гармоники .



$$\varphi_{\text{jet}} - \Psi_{\text{EP},\,2}^{\text{V0}} = \frac{\pi}{2}$$

$$N_{\text{in}} = \int_{in} \frac{dN_{\text{jet}}}{d(\varphi_{\text{jet}} - \Psi_{\text{EP},\,2}^{\text{V0}})} = a\left(\pi + 4v_2^{\text{ch jet}}\right)$$

$$N_{\text{out}} = \int_{out} \frac{dN_{\text{jet}}}{d(\varphi_{\text{jet}} - \Psi_{\text{EP},\,2}^{\text{V0}})} = a\left(\pi - 4v_2^{\text{ch jet}}\right)$$

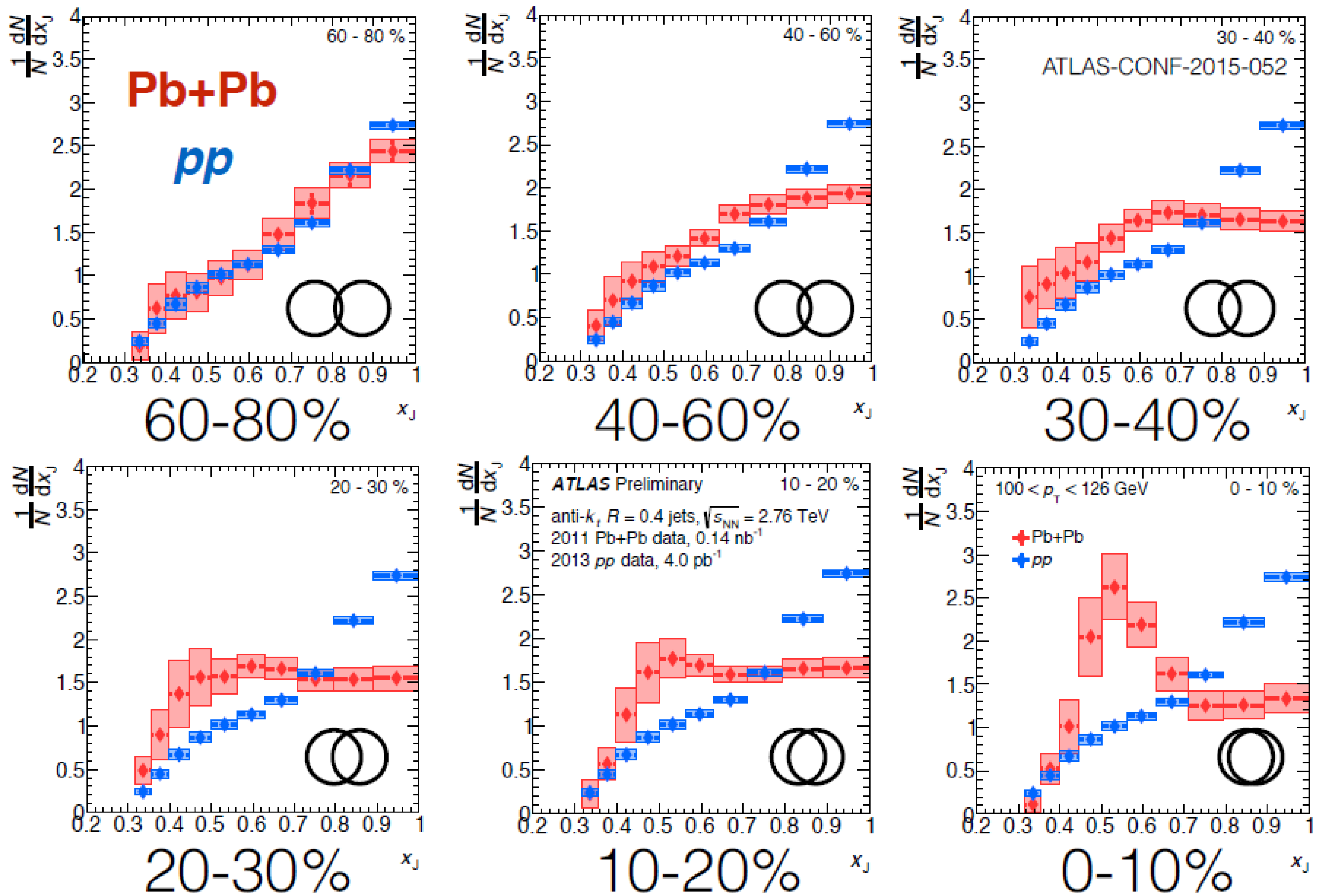


Different energy scales for v_2^{part}, $v_2^{\text{ch jet}}$ and $v_2^{\text{ch+emjet}}$, qualitative comparison only

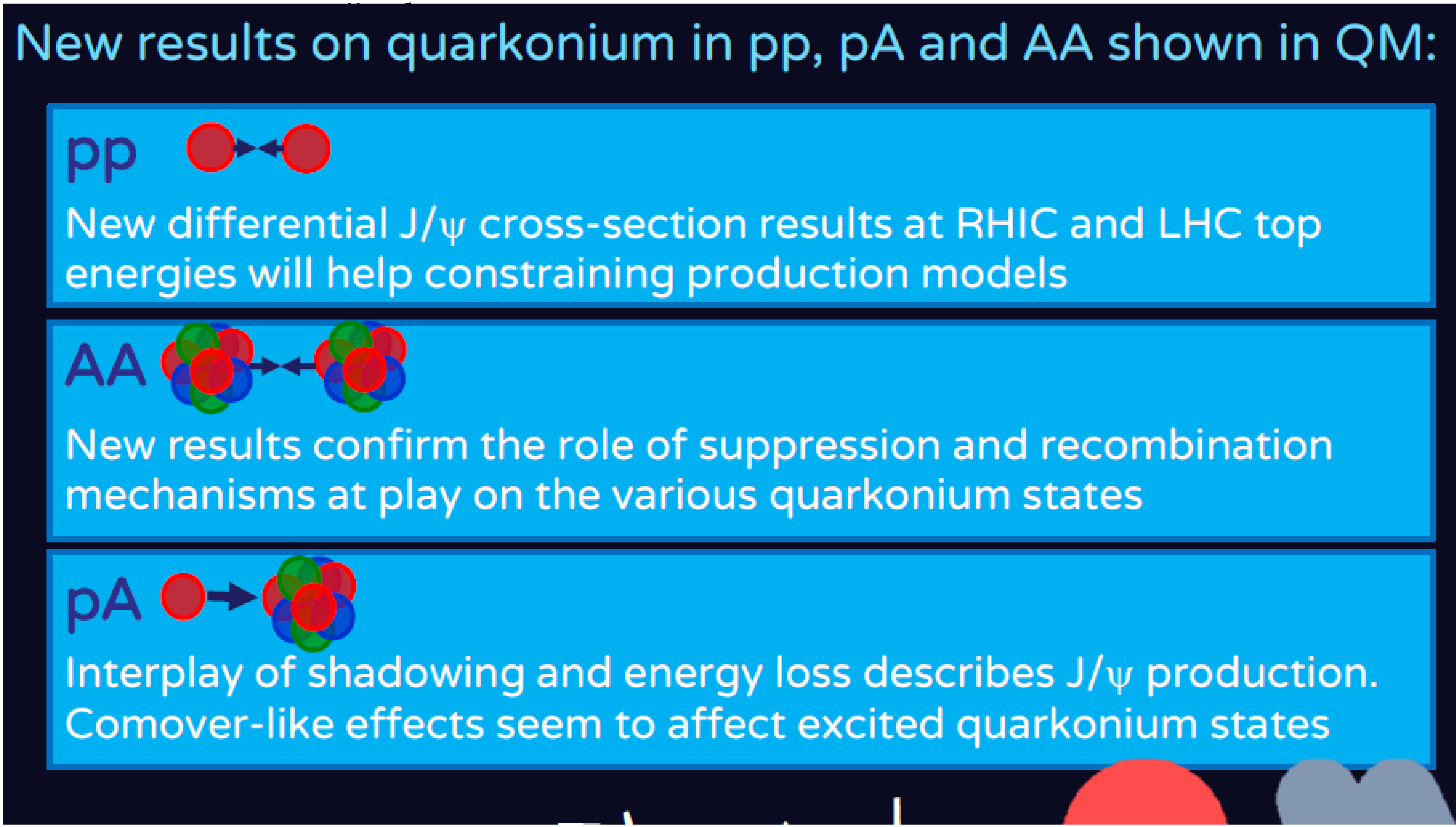
Е.Н. Назарова «Дисбалланс струй с учётом unfolding», (на основе доклада D.Perepelitsa, “ New results on fully corrected dijet asymmetry in Pb+Pb collisions with ATLAS”, dvp-QM15-ATLAS- 9-29-15_Perepelitsa and dvp-EPSHEP-7-23-15_Perepeltsa_jets.pdf + J.Jia, ATLAS-CONF-2015-052.pdf)

Unfolding дисбалланса струй необходим для последующего сравнения с теорией. Новая задача для анализа CMS в этом направлении.

x_J for $p_{T,1}$ > 100 GeV, vs. centrality



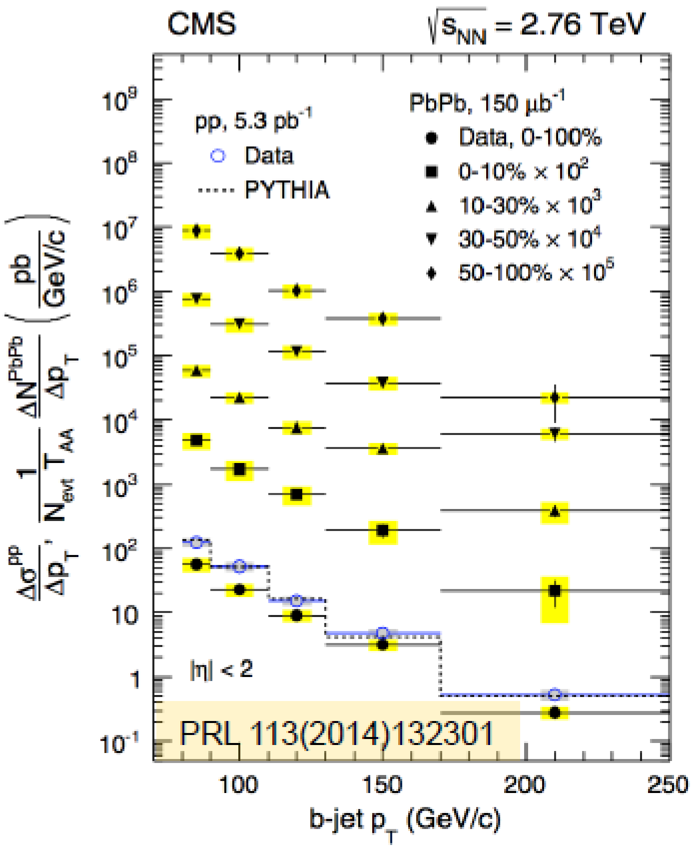
С. Образцов «Experimental overview on quarkoniumproduction» (на основе доклада R. Arnaldi “Experimental overview on quarkoniumproduction”)

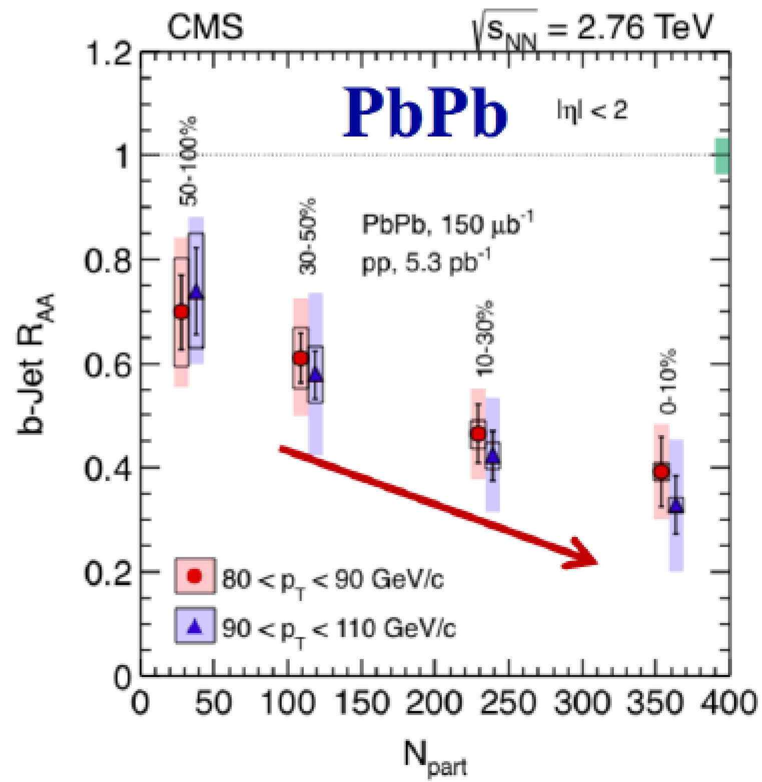


А. Беляев « Open heavy-flavor measurements» (на основе доклада R. Averbeck “Experimental overview on quarkoniumproduction”)

Хороший обзор по адронам с тяжёлым ароматом.

B-jet suppression at the LHC

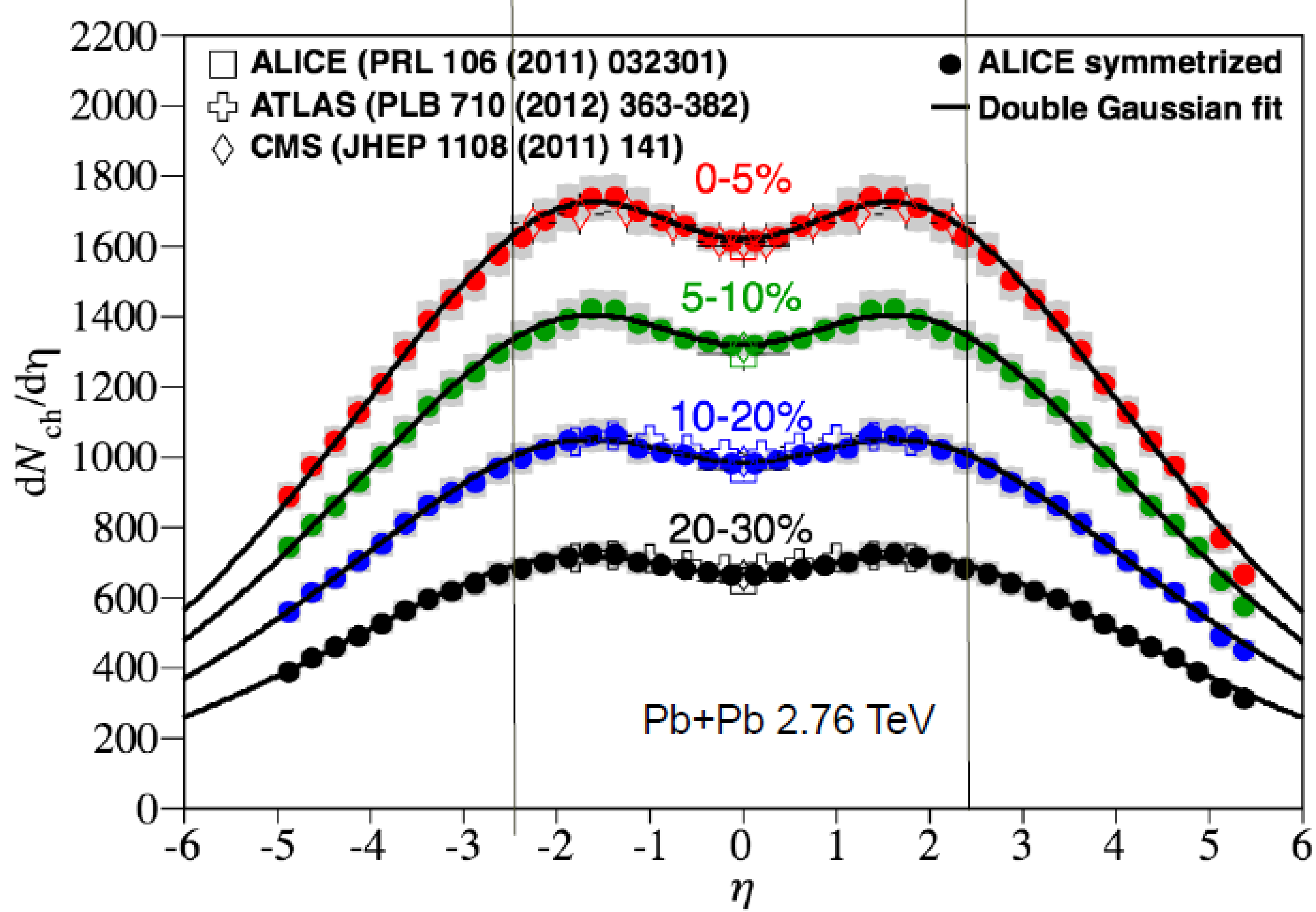




- **fully reconstructed b jets in Pb-Pb collisions at 2.76 TeV**

END

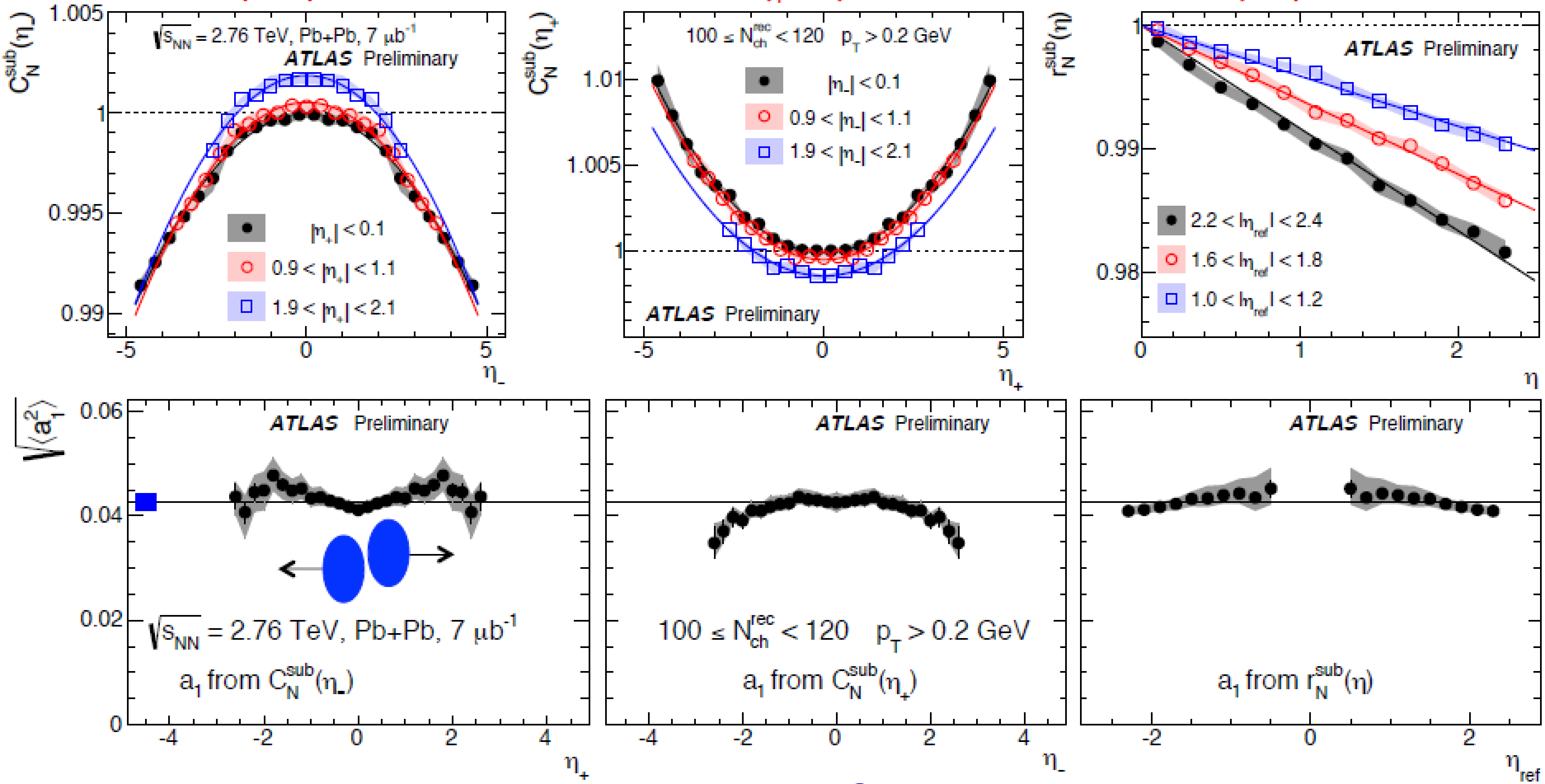
ALICE dN/dη distribution



Projections of CF in Pb+Pb

$$C_N^{\mathrm{sub}}(\eta_1,\eta_2) \approx 1 + \langle a_1^2\rangle \eta_1\eta_2 = 1 + \frac{\langle a_1^2\rangle}{4}(\eta_+^2 - \eta_-^2) \qquad r_N^{\mathrm{sub}}(\eta,\eta_{\mathrm{ref}}) = 1 - 2\langle a_1^2\rangle |\eta_{\mathrm{ref}}|\,\eta$$

Fit η_- dependence — Fit η_+ dependence — Fit η dependence



- Consistent a_1 at different slices → LRC dominated by a_1.

Consistent between four methods

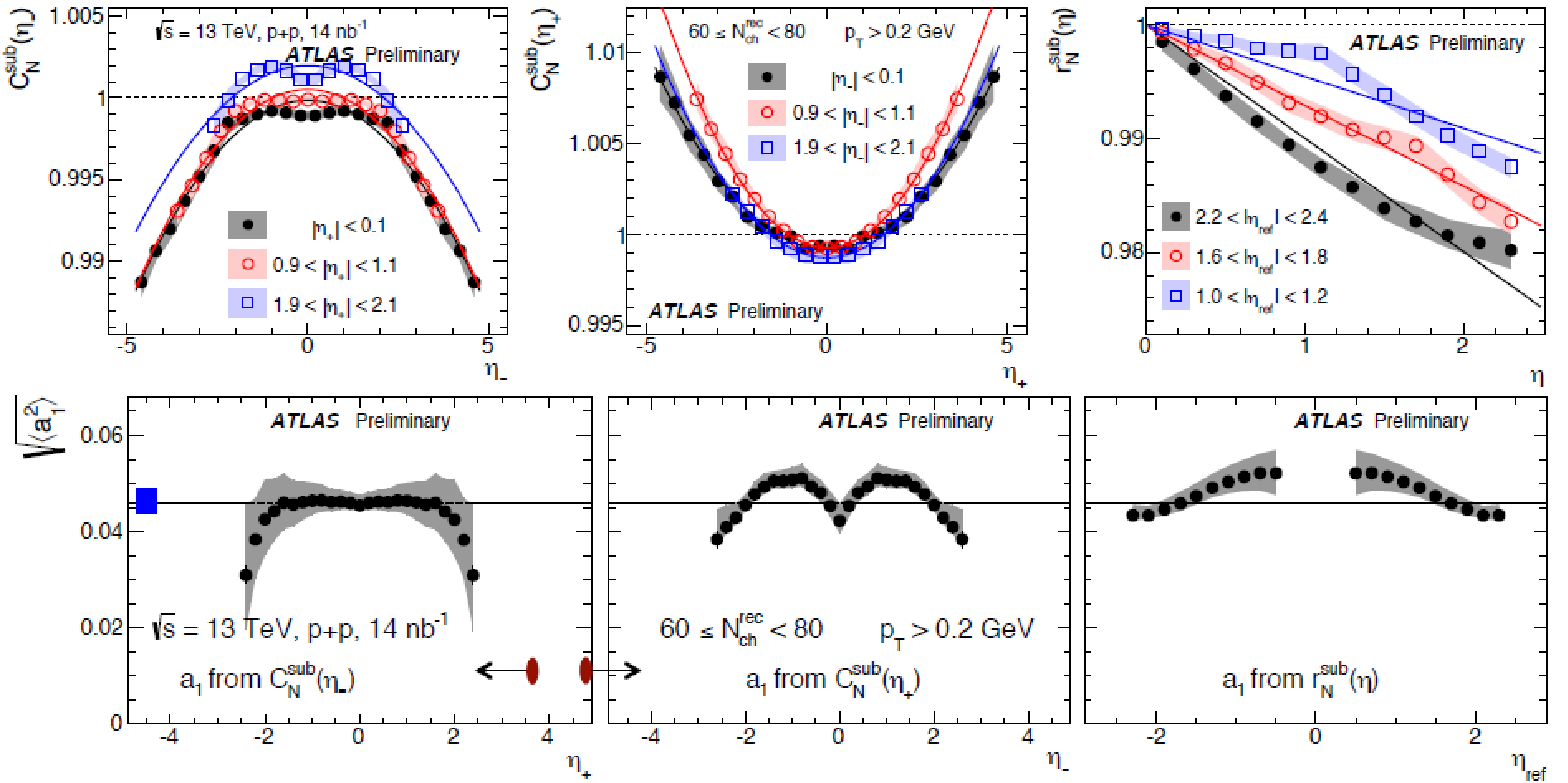
Projections of CF in p+p

$$C_N^{sub}(\eta_1,\eta_2) \approx 1 + \langle a_1^2\rangle \eta_1\eta_2 = 1 + \frac{\langle a_1^2\rangle}{4}(\eta_+^2 - \eta_-^2) \qquad r_N^{sub}(\eta,\eta_{ref}) = 1 - 2\langle a_1^2\rangle |\eta_{ref}|\,\eta$$

Fit η_- dependence

Fit η_+ dependence

Fit η dependence

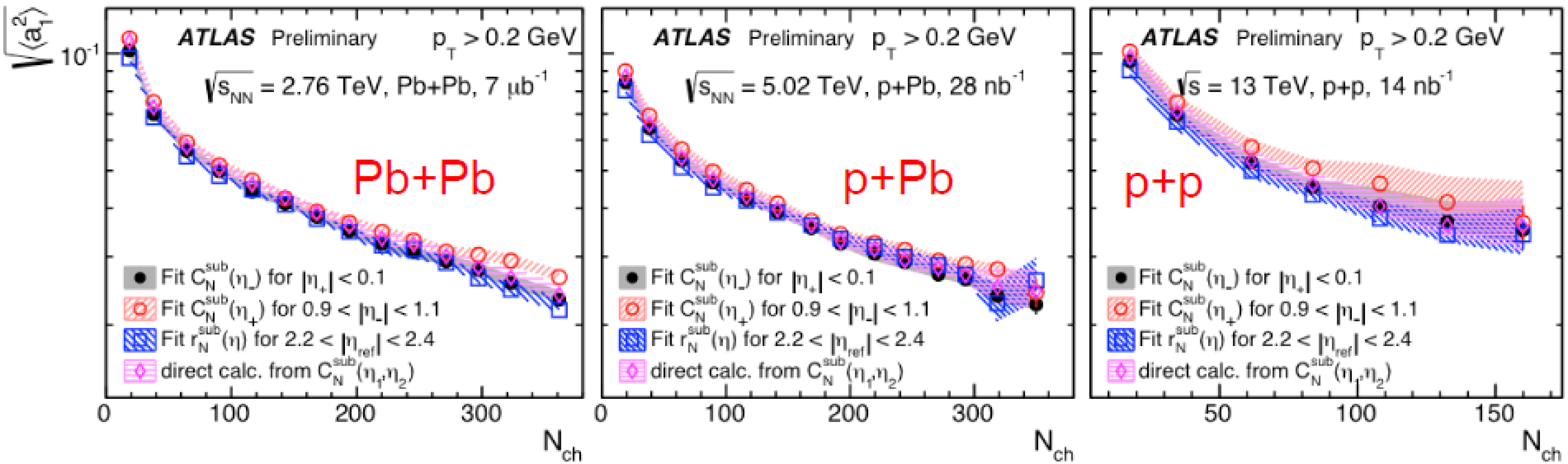


- Consistent a_1 at different slices → LRC dominated by a_1.

Consistent between four methods

a_1 from four methods

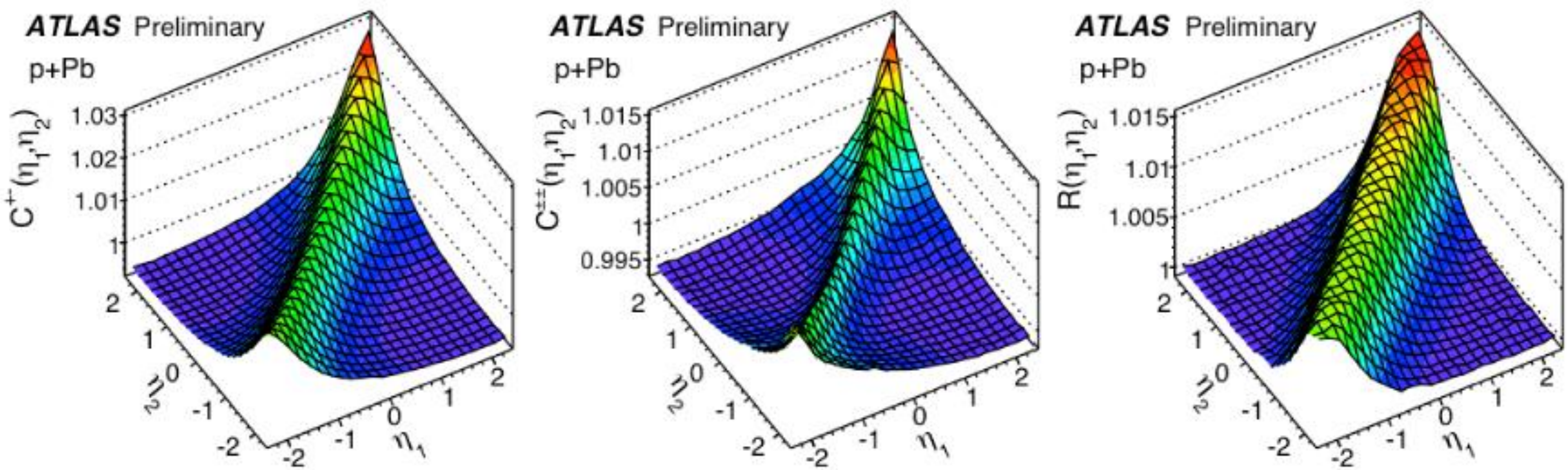
- (i) Quadratic fit to η- direction, $C_N^{sub}(\eta_-)|_{|\eta_+|<0.1}$
- (ii) Quadratic fit to η+ direction, $C_N^{sub}(\eta_+)|_{0.9<|\eta_-|<1.1}$
- (iii) Linear fit to r correlator, $r_N^{sub}(\eta)|_{2.2<|\eta_{ref}|<2.4}$
- (iv) Legendre expansion



4 methods consistent with each other in all three collision systems

Properties of SRC in p+Pb

- Most of the FB asymmetry is in the magnitude of the SRC.
- η_--width of SRC is constant as a function of η_+.

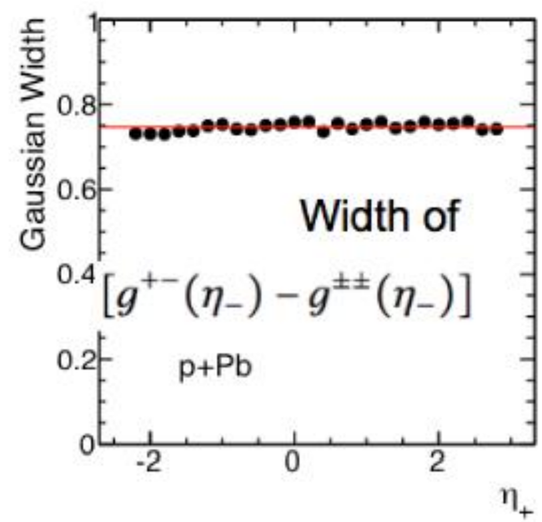


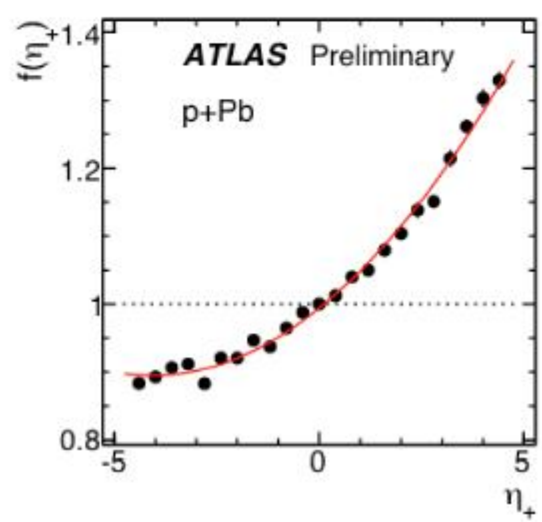
ATLAS Preliminary

$200 \leq N_{ch}^{rec} < 220$

$\sqrt{s_{NN}} = 5.02$ TeV, p+Pb, 28 nb^{-1}

$p_T > 0.2$ GeV

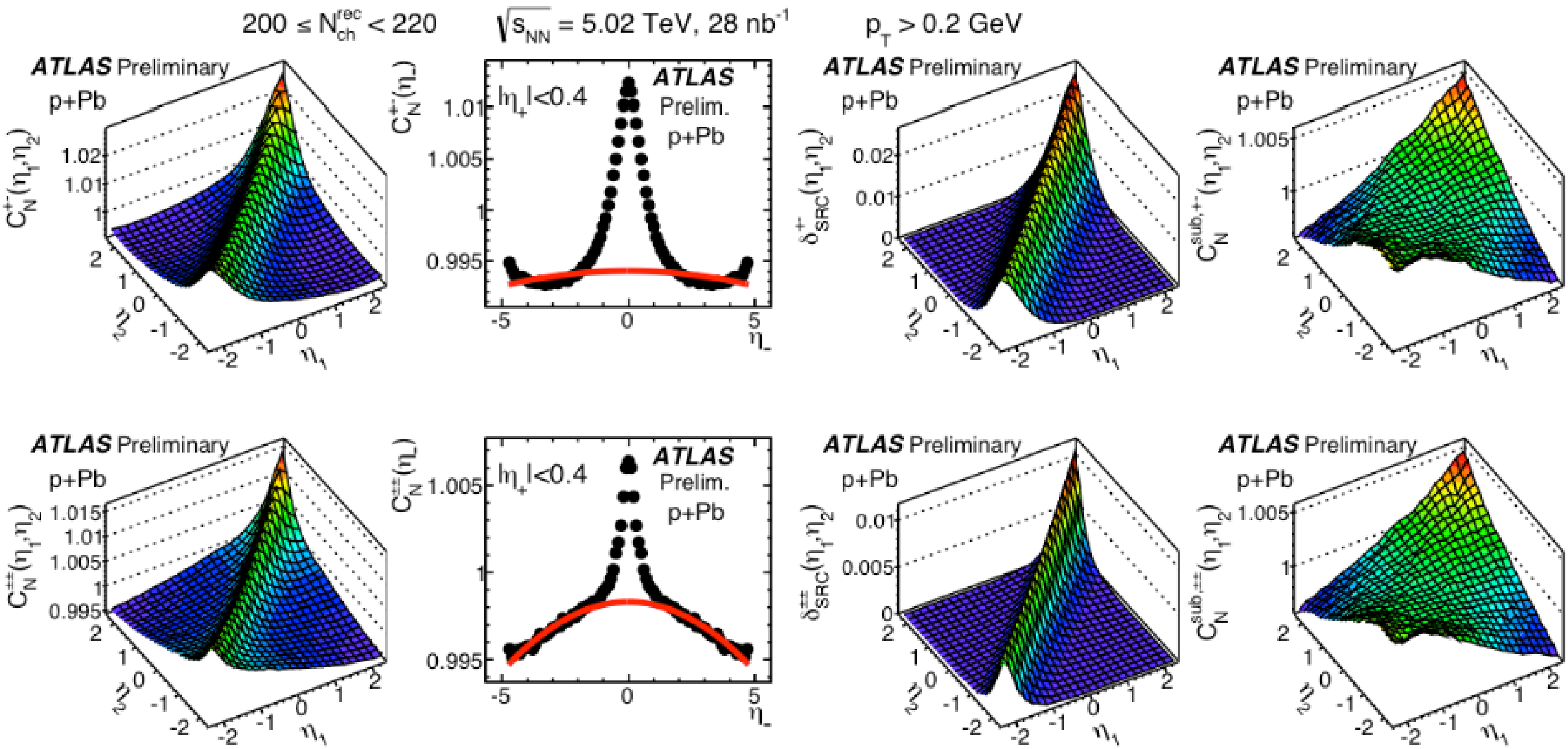




Estimation of the SRC in pPb

$$R(\eta_+,\eta_-) \approx 1 + f(\eta_+)\left[g^{+-}(\eta_-) - g^{\pm\pm}(\eta_-)\right], \quad \delta_{SRC}^{+-} = f(\eta_+)g^{+-}(\eta_-), \quad \delta_{SRC}^{\pm\pm} = f(\eta_+)g^{\pm\pm}(\eta_-)$$

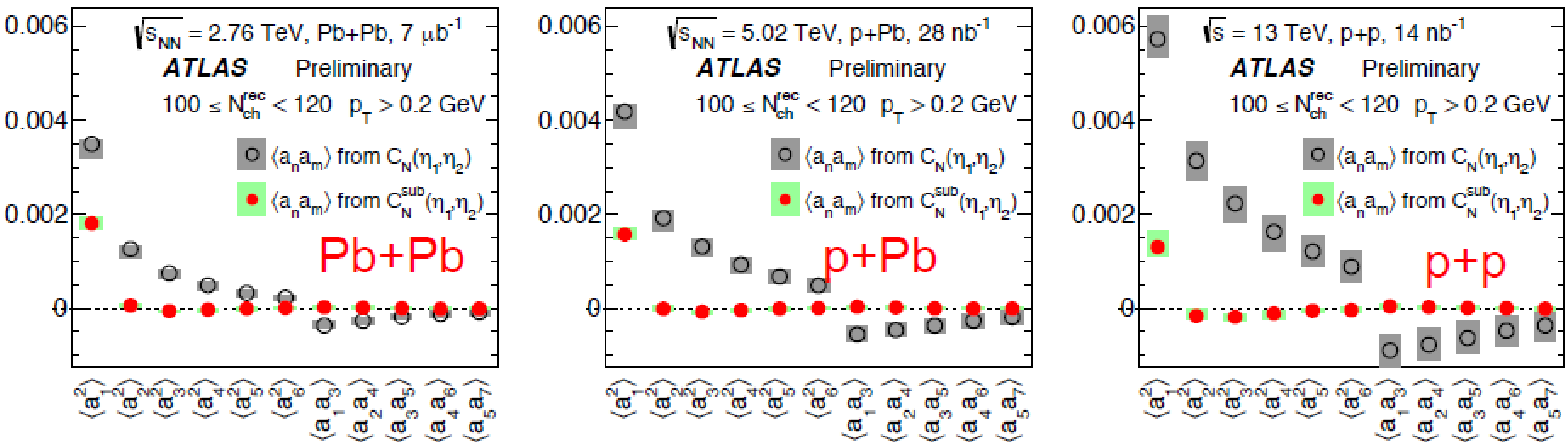
- Asymmetry between proton-going and lead-going direc is due to SRC
- LRC is very symmetric



- The LRC, $C_N^{sub}(\eta_+,\eta_-)$, has similar magnitude between charge combinations.

Legendre spectra before and after subtraction

$$C_N(\eta_1,\eta_2) \text{ or } C_N^{sub}(\eta_1,\eta_2) = 1 + \sum_{n,m=1}^{\infty} \langle a_n a_m \rangle \frac{T_n(\eta_1)T_m(\eta_2) + T_n(\eta_2)T_m(\eta_1)}{2}$$



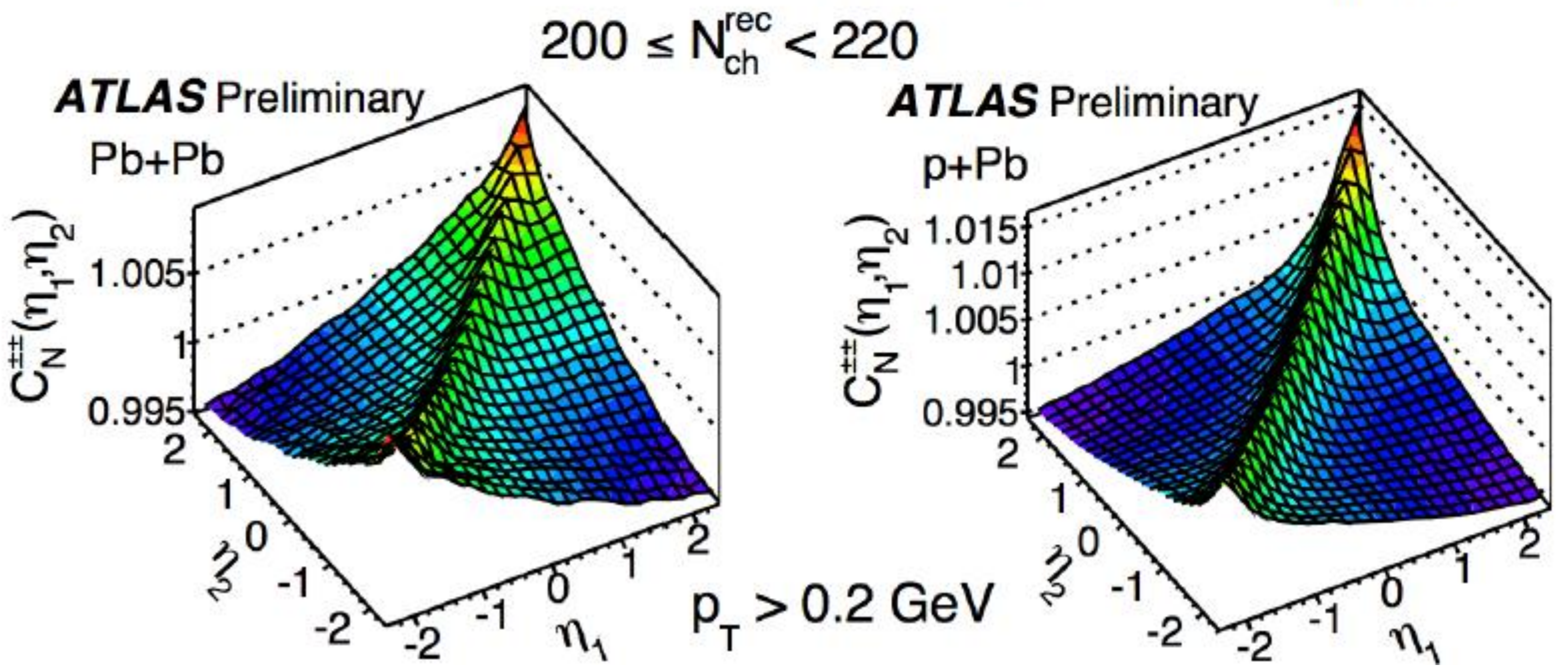
- a_n values significantly reduced after SRC subtraction
  - Dominated by a_1.

Constructing correlation function

- Signal and Background distributions
  - Tracks from events with similar N_{ch} and z_{vtx}

$$C = \frac{\langle N(\eta_1)N(\eta_2)\rangle}{\langle N(\eta_1)\rangle\langle N(\eta_2)\rangle} = \frac{S(\eta_1,\eta_2)}{B(\eta_1,\eta_2)}$$

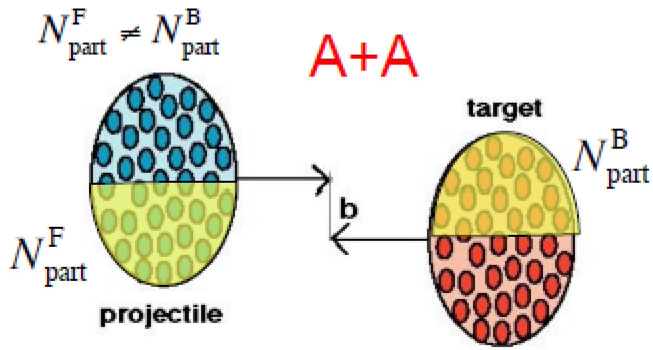
- Due to symmetry in PbPb or pp, only one quadrant is independent.
  - $\eta_-=\eta_1-\eta_2>0$, $\eta_+=\eta_1+\eta_2>0$ $\quad C_N(\eta_1,\eta_2) = C_N(\eta_2,\eta_1)$ $\quad C_N(\eta_1,\eta_2) = C_N(-\eta_1,-\eta_2)$
- In pPb collision, only one half is independent
  - $\eta_-=\eta_1-\eta_2>0$ $\quad C_N(\eta_1,\eta_2) = C_N(\eta_2,\eta_1)$
  - But distribution can be symmetrized in any case to compare PbPb and pp

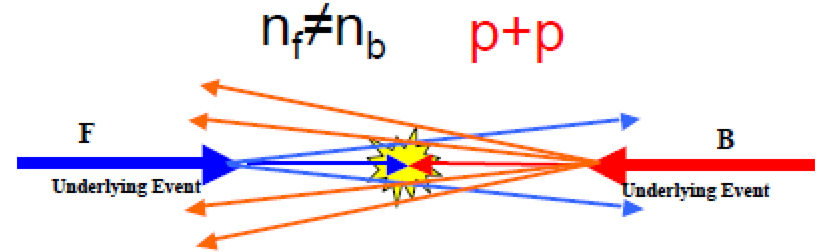


Запасные слайды

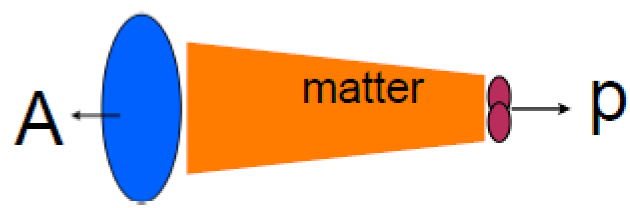
Origin of pseudorapidity correlations

- dN/dη shape reflects asymmetry in num. of forward/backward sources
  - Sources can be wounded nucleons, or partons in nucleons (MPI)

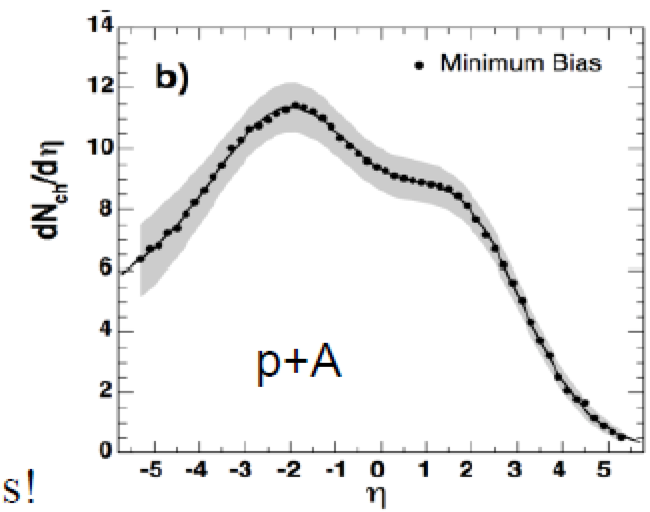




- Asymmetry seen directly in p+A collisions



$$dN/d\eta \;\propto\; f^{\rm F}(\eta)N_{\rm part}^{\rm F} + f^{\rm B}(\eta)N_{\rm part}^{\rm B}$$

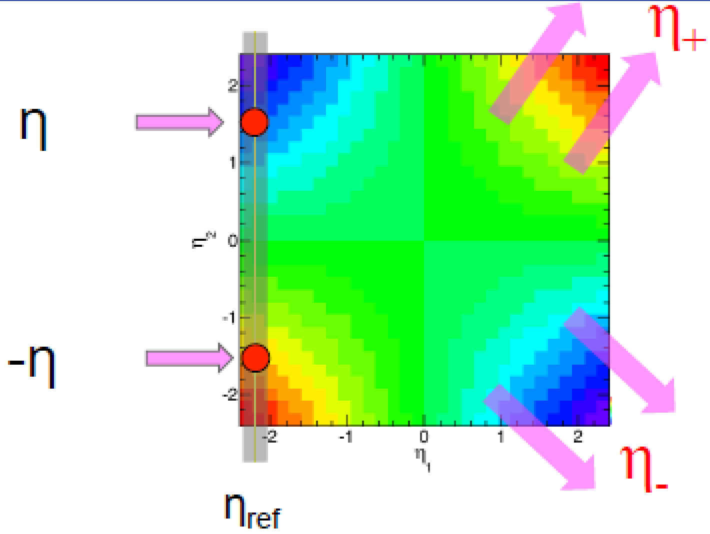


  - Naturally exists in A+A collisions on EbyE bases!

- Goal: understand event-by-event fluctuation of dN/dη

1. Probes early time dynamics, longitudinal flow, final state effects.
2. Inputs for 3+1D hydrodynamic models **W/O** boost invariance

Projections of correlation function



CF dominated by a_1, thus:

$$C_N^{sub}(\eta_1,\eta_2) \approx 1 + \langle a_1^2 \rangle \eta_1\eta_2 = 1 + \frac{\langle a_1^2 \rangle}{4}(\eta_+^2 - \eta_-^2)$$

2. Quadratic fit of $C_N^{sub}(\eta_-)$ in narrow slice of η_+, this gives a_1 as a function of η_+.
3. Quadratic fit of $C_N^{sub}(\eta_+)$ in narrow slice of η_-, this gives a_1 as a function of η_-.
4. Linear fit of the η dependence of $r_N^{sub}(\eta,\eta_{ref})$ in narrow slice of η_{ref}.

$$r_N^{sub}(\eta,\eta_{ref}) = C_N^{sub}(-\eta,\eta_{ref})/C_N^{sub}(\eta,\eta_{ref}) = 1 - 2\langle a_1^2 \rangle \eta\eta_{ref}$$

similar to the CMS correlator for flow decorrelation 1503.01692

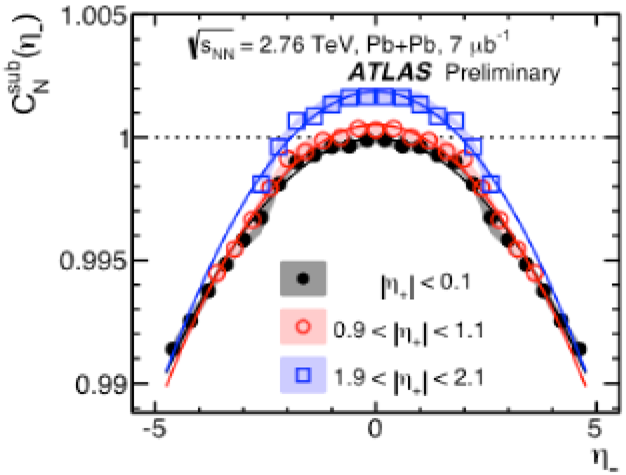
Compare to a_1 obtained from Legendre expansion method

Fit in limited η_1 and η_2 space, the systematics largely independent!

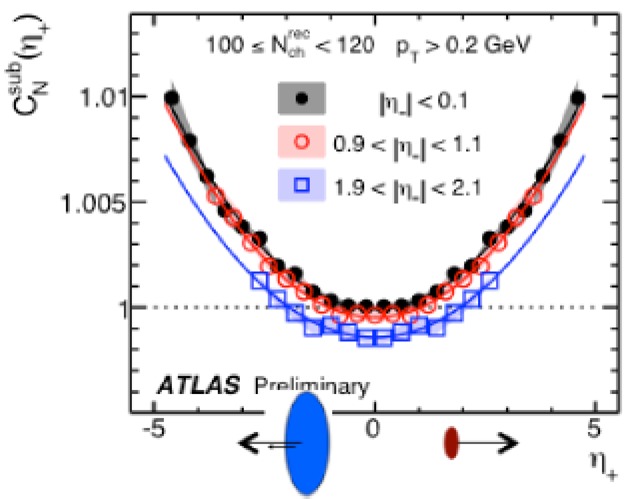
Projections of CF in p+Pb

$$C_N^{\mathrm{sub}}(\eta_1,\eta_2) \approx 1 + \langle a_1^2 \rangle \eta_1\eta_2 = 1 + \frac{\langle a_1^2 \rangle}{4}(\eta_+^2 - \eta_-^2) \qquad r_N^{\mathrm{sub}}(\eta,\eta_{\mathrm{ref}}) = 1 - 2\langle a_1^2 \rangle |\eta_{\mathrm{ref}}|\, \eta$$

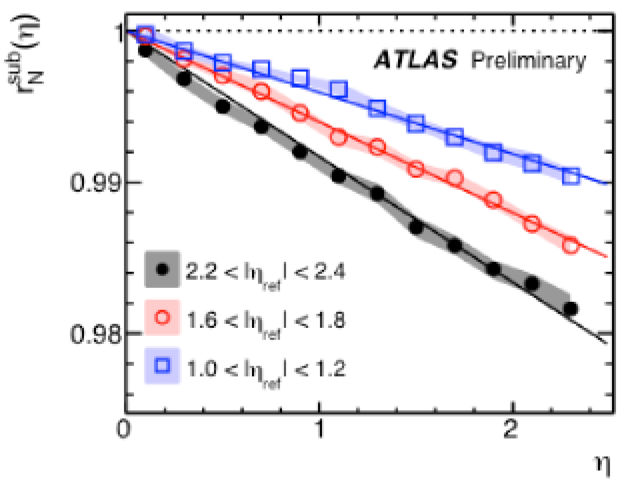
Fit η_- dependence



Fit η_+ dependence



Fit η dependence



Projections of CF in p+Pb

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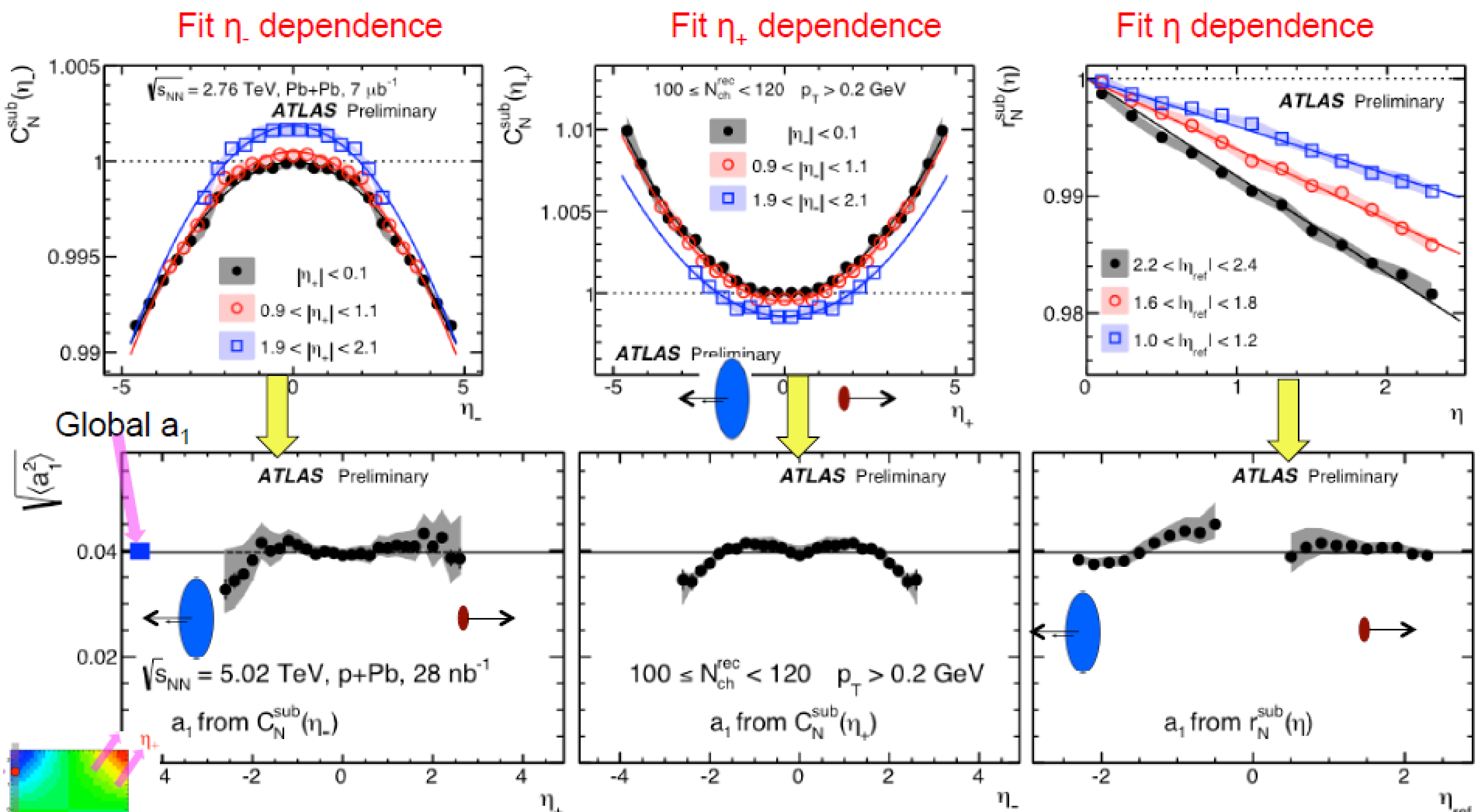

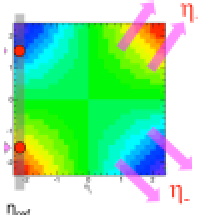

LRC is ~symmetric between proton- and lead-going side!

. Theory

Rapidity Correlations at Fixed Multiplicity in Cluster Emission Models, thesis

Edmond L. Berger (CERN). May 1974. 60 pp.

Published in **Nucl.Phys. B85 (1975) 61**

CERN/D.Ph.II/PHYS 74-17, CERN-TH-1800

DOI: 10.1016/0550-3213(75)90557-X

Возможные доклады сотрудников

Далее мои рекомендации – предложения (можно также выбрать самостоятельно из QM2015) некоторым сотрудникам, работающим в соответствующих направлениях.

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Работа интересна тем, что впервые доказан экспериментально разный выход струй в зависимости от угла плоскости реакции для второй гармоники и выполнен unfolding дисбаланса струй.

Г.Х. Эйюбова «Гармоники длинно действующих корреляций в pp столкновениях» (на основе доклада Zhenyu Chen «Anisotropy harmonics from long-range correletions in high multiplicity pp collisions» QM15_Zhenyu_v6_Vn_high_multi.pdf)

Полное и детальное исследование анизотропных гармоник в pp столкновениях, включая идентификацию частиц, Double Ridge в pp. Не плохо бы сравнить с нашей теор-публикацией по V2 в pp столкновениях с D. D’Enterria

Е.Н. Назарова «Дисбалланс струй с учётом unfolding», (на основе доклада D.Perepelitsa, “ New results on fully corrected dijet asymmetry in Pb+Pb collisions with ATLAS”, dvp-QM15-ATLAS- 9-29-15_Perepelitsa and dvp-EPSHEP-7-23-15_Perepeltsa_jets.pdf + J.Jia, ATLAS-CONF-2015-052.pdf)

Unfolding дисбалланса струй, необходимый для сравнения с теорией, и возможности CMS в этом направлении.

С. Образцов «Experimental overview on quarkoniumproduction» (на основе доклада R. Arnaldi “Experimental overview on quarkoniumproduction”)

Хороший обзор по кваркониям.

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Хороший обзор по адронам с тяжёлым ароматом.

Summary

- Two-particle correlation $C_N(\eta_1,\eta_2)$ measured in PbPb, pPb and pp collisions for p_T>0.2 GeV and $|\eta|$<2.4 at similar event multiplicity N_{ch}.
  - Sum of a short-range component (SRC) + a long-range component (LRC).

- Data-driven method to separate SRC and LRC based on the fact that SRC differs between +- and ±± pairs, but not for LRC
  - LRC is symmetric in all systems, but in pPb SRC is asymmetric for η and $-\eta$.
  - LRC consistent with $1+\langle a^2{}_1\rangle\eta_1\eta_2$, $\langle a^2{}_1\rangle$ is extracted via Legendre expansion as well as from the projections of the LRC in limited η_1,η_2 phase space

- N_{ch}-scaling of LRC (via a_1) and SRC are studied
  - LRC (via a_1) controlled by N_{ch}, not by collision systems or charge combination
  - SRC depends strongly on collision system and charge combination
  - N_{ch} dependence of LRC and SRC follows power-law with an index close to 0.5 → relation to the number of sources for particle production?

Important inputs for 3+1D hydrodynamic models **W/O** boost invariance
Insights on particle production, longitudinal transport, final-state effects

See works by Bzdak, Bozek, Broniowski1509.02967,1509.04124; , Akihiko, Schenke 1509.04103

Выводы

- Двух- частичные корреляции $C_N(\eta_1, \eta_2)$ измерены в PbPb, pPb и pp столкновениях при pt>0.2 GeV и $|\eta|<2.4$ при одинаковых множественностях события.
  - Получено разложение на сумму SRC и LRC.

- Разделение на SRC и LRC выполнено экспериментально на основе того, что для SRC наблюдается отличие между $+-$ и $\pm\pm$ парами, но его нет для LRC.
  - LRC симметрично для всех систем, но асимметрично для pPb для η и $-\eta$.
  - LRC соответствует зависимости $1+\langle a^2{}_1\rangle \eta_1\eta_2$, где $\langle a^2{}_1\rangle$ - коэффициент разложения по полиномам Лежандра в узком интервале фазового пространства (η_1, η_2).

- Исследовался N_{ch}- скелинг LRC и SRC по параметру $\langle a^2{}_1\rangle$
  - LRC контролируются множественностью N_{ch} , но не размером систем или комбинацией зарядов.
  - SRC сильно зависят от сталкивающихся систем и от комбинации зарядов.
  - N_{ch} – зависимость LRC и SRC следует степенной функции с показателем , близким к α = -0.5,
  - Предполагается связь с числом источников испускаемых частиц