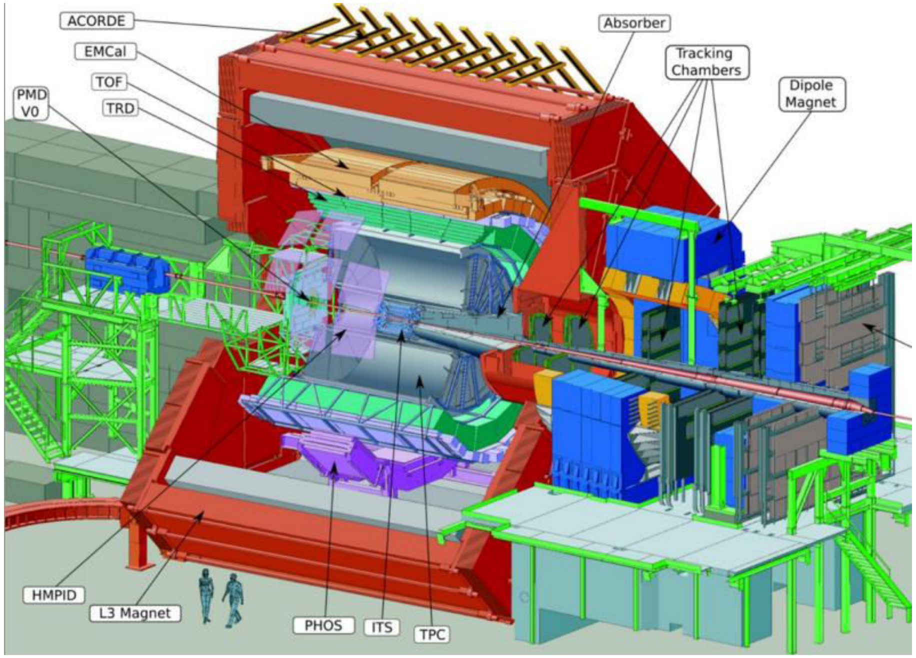
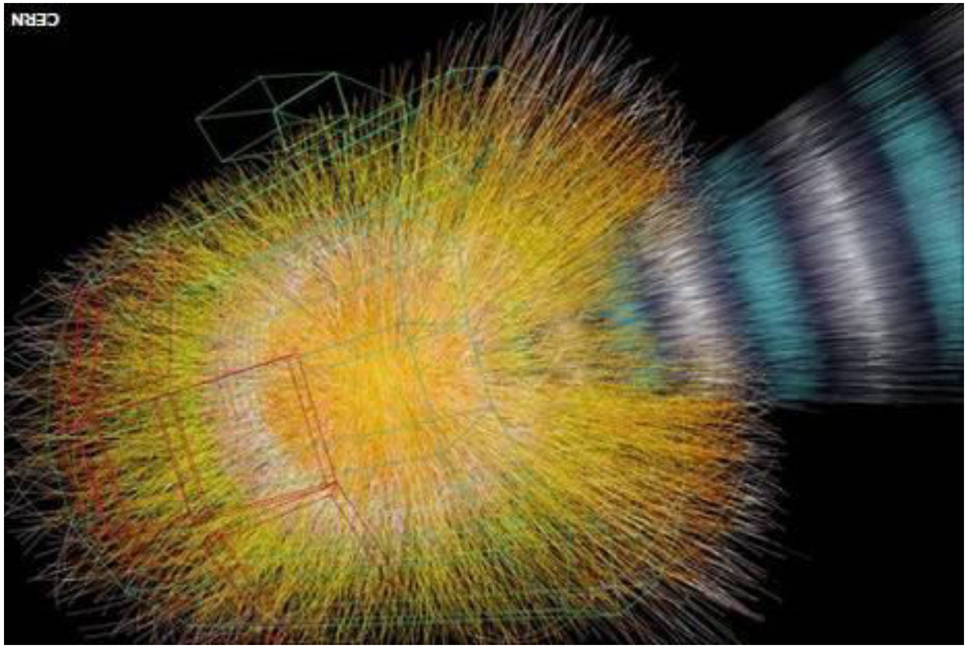
Эксперимент ALICE

В. Рябов (ЛРЯФ)

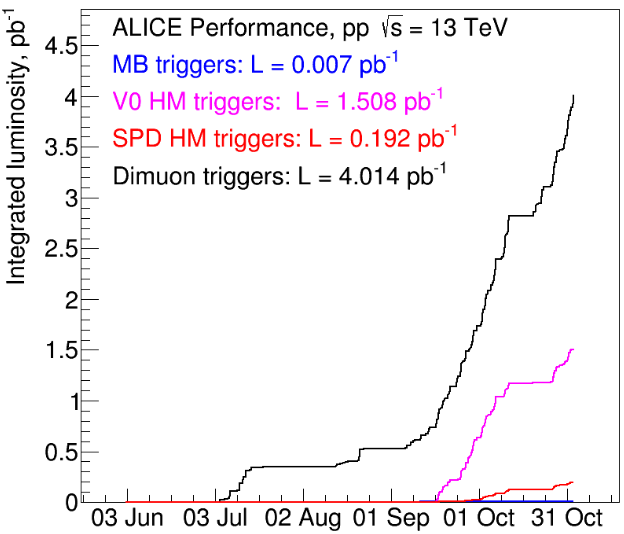




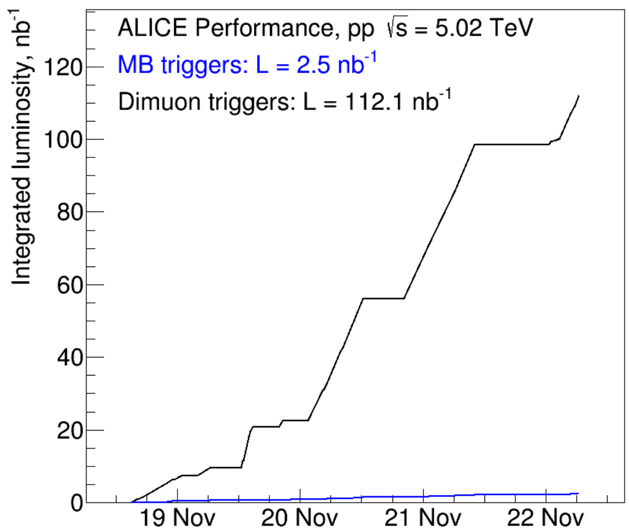
Run-II, 2015

- Дооснащение детекторных подсистем: TRD, PHOS, AD детектор

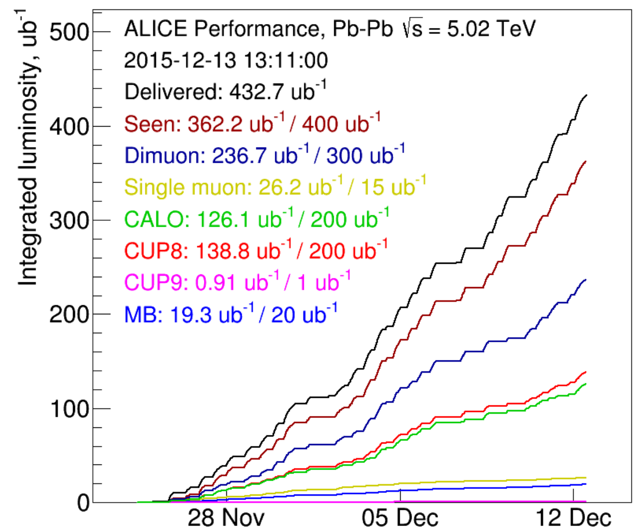
pp@13 TeV



pp@5 TeV



PbPb@5 TeV



- MinBias: 600 M → 0.007 pb^{-1}
- V0 HM: 123 M → 1.508 pb^{-1}
- SPD HM: 109 M → 0.192 pb^{-1}
- Di-μ: 4.014 pb^{-1}

- MinBias: 128 M → 2.5 nb^{-1}
- Di-μ: 112.1 nb^{-1}

- MinBias: 157 M → 19.3 μb^{-1}
- Seen: 362.2 μb^{-1}

Участие ЛРЯФ в ALICE

- Экспертное сопровождение и ремонт мюонных камер
- Участие в наборе данных (60 смен)
- Координация работы и модернизация триггерной системы
- Участие в работе рабочей группы по отбору физических событий и треков
- Руководство работой рабочей физической группы по резонансам
- Физический анализ экспериментальных данных:
  - ✓ ультрапериферические столкновения, фоторождение J/Ψ
  - ✓ легкие адроны
  - ✓ дальние корреляции
- Теоретическое сопровождение и интерпретация экспериментальных результатов
- Участие во многочисленных PC, IRC; работе рабочих групп и т.д.

- Участие в программе обновления экспериментальной установки → В. Никулин

Основные публикации

- 47 коллаборационных статей:

  - ✓ Forward-central two-particle correlations in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1506.08032
  - ✓ ALICE Collaboration. First results of the ALICE detector performance at 13 TeV, ALICE-PUBLIC-2015-004
  - ✓ K*(892) and Φ(1020) production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, Phys.Rev. C91 (2015) 024609
  - ✓ Coherent ψ(2S) photo-production in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, Phys.Lett. B751 (2015)
  - ✓ Coherent ρ0 photoproduction in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, JHEP 1509 (2015) 095
  - ✓ Measurement of an excess in the yield of J/ψ at very low p_T in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, arXiv:1509.08802
  - ✓ Nuclear gluon densities at small x from photoproduction of J/Ψ in ultraperipheral collisions at the LHC, Bulletin of the Russian Academy of Sciences. Physics, 2015, Vol. 79, No. 7, pp. 912–920
  - ✓ Nuclear shadowing in photoproduction of ρ mesons in ultraperipheral nucleus collisions at RHIC and the LHC, Phys.Lett. B752 (2016) 51-58

Основные конференции

- 8 докладов на ведущих конференциях + материалы:
  - ✓ XXII International Workshop on High Energy Physics and Quantum Field Theory, Samara, 24-31 June
  - ✓ LHCP-2015, Saint-Petersburg, 31 August
  - ✓ SQM-2015, Dubna, 6-11 July
  - ✓ Quark Matter 2015, Kobe, Japan, Sep 27- Oct 3
  - ✓ Nucleus-2015, St. Petersburg, June 29-July 3, 2015
  - ✓ New Directions in Nuclear Deep Inelastic Scattering, ECT*, Trento, Italy, June 8-12, 2015
  - ✓ Workshop “High Energy Nuclear Physics with Spectator Tagging”, Norfolk, USA, March 9-11, 2015

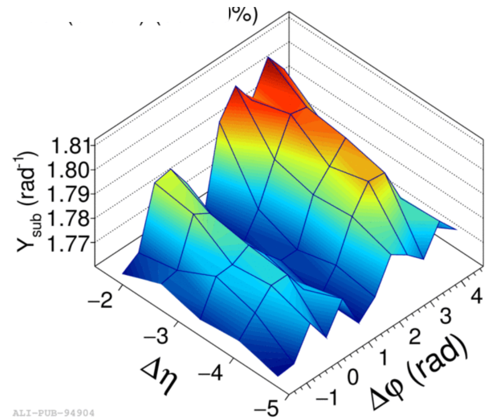
Forward μ -central two-particle correlations, p+Pb, $\sqrt{s_{NN}}$ = 5.02 ТэВ

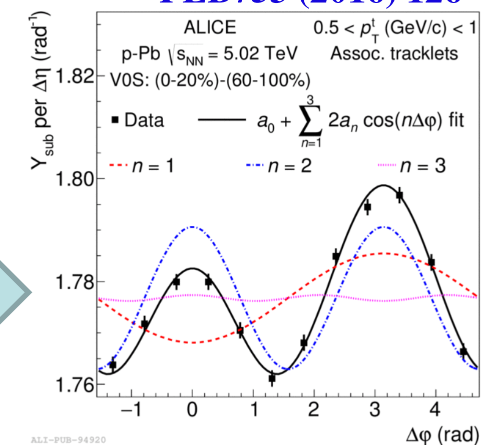
- Forward μ: -4 < η < -2.5
- Central tracklets: |η| < 1
- Две конфигурации: p-Pb и Pb-p
- (0-20%) – (60-100%) → подавление струеподобных вкладов
- Корреляция сохраняется: |Δη| = 5, η~4

(0-20%)-(60-100%)

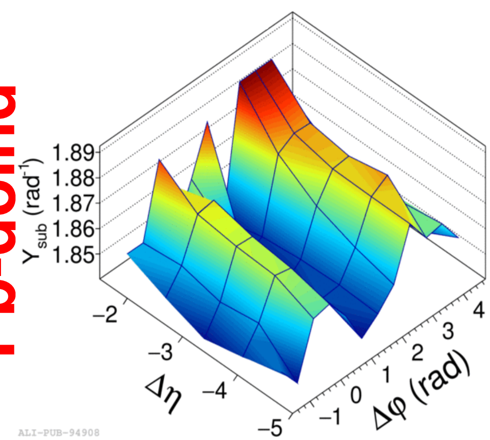
PLB753 (2016) 126

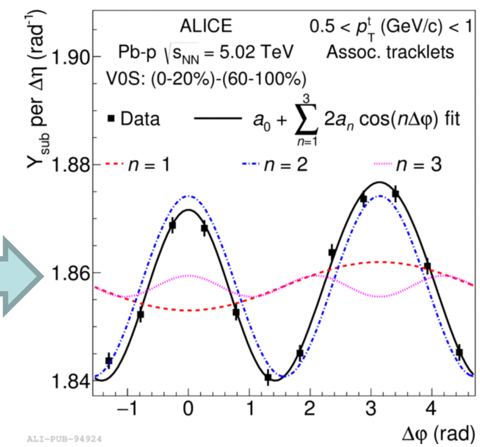
p-going





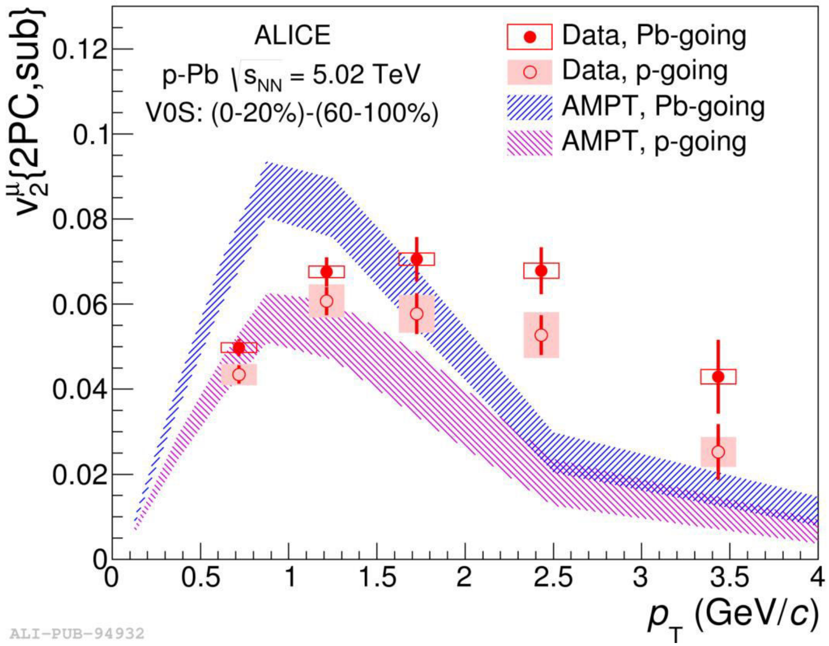
Pb-going

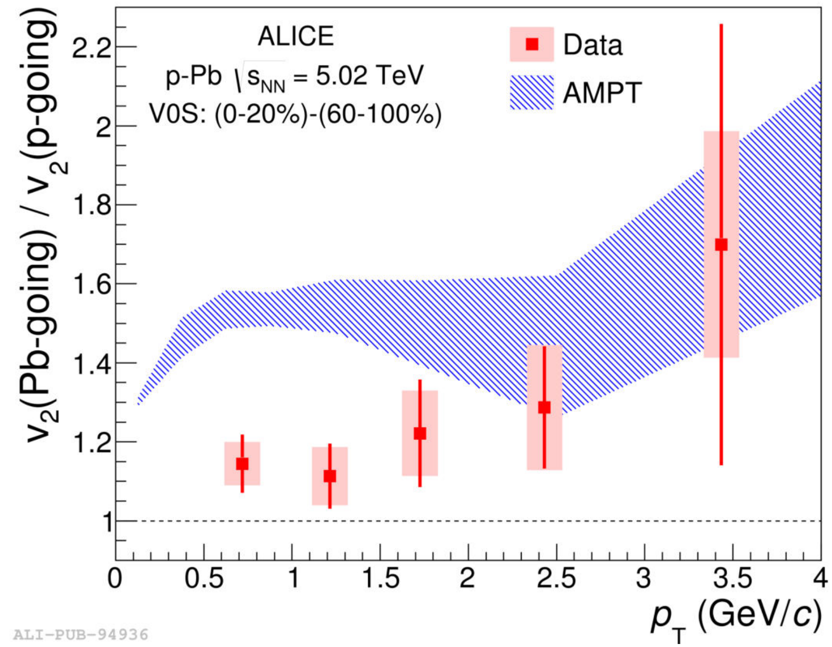




Эллиптический поток v_2, p+Pb, $\sqrt{s_{NN}}$ = 5.02 ТэВ

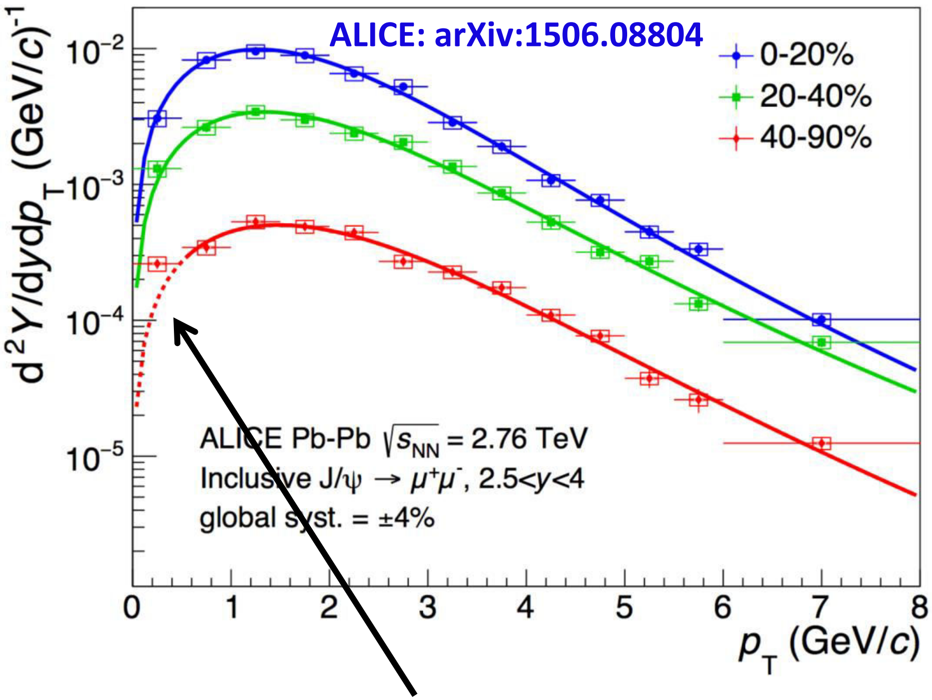
PLB753 (2016) 126



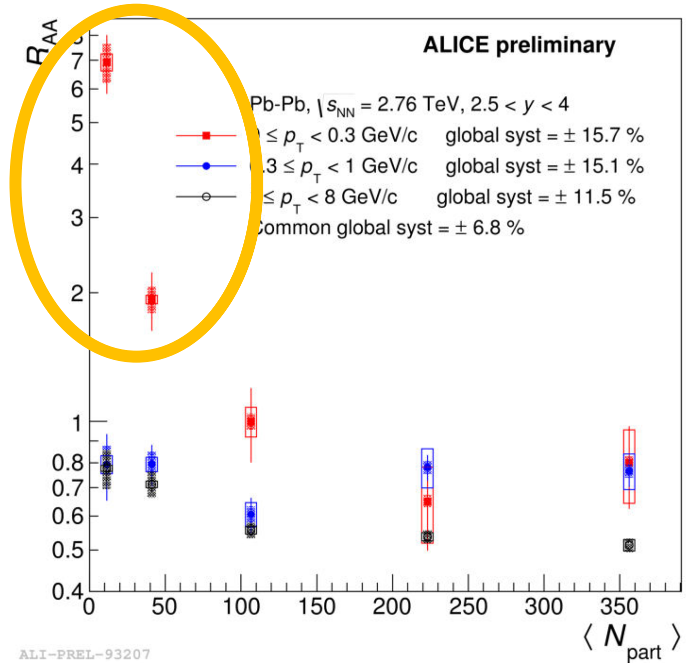


- v_2(Pb-going) > v_2(p-going), качественно согласуется с гидродинамикой
- Измеренные зависимости не описываются AMPT
- Состав мюонов и их v_2 могут различаться в Pb-going и p-going направлениях

Избыточный выход J/Ψ, Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV



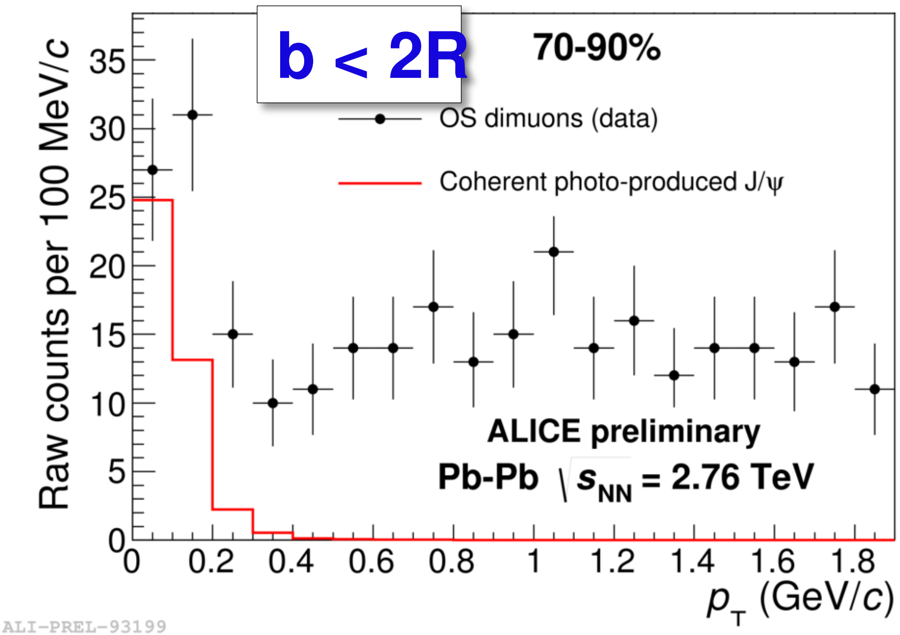
$$R_{AA} = \frac{N_{AA}^{J/\psi}}{\langle N_{coll}\rangle \, N_{pp}^{J/\psi}} \quad \begin{array}{l} = 1 \;\rightarrow\; \text{No medium effect} \\ < 1 \;\rightarrow\; \text{Suppression} \\ > 1 \;\rightarrow\; \text{Enhancement} \end{array}$$

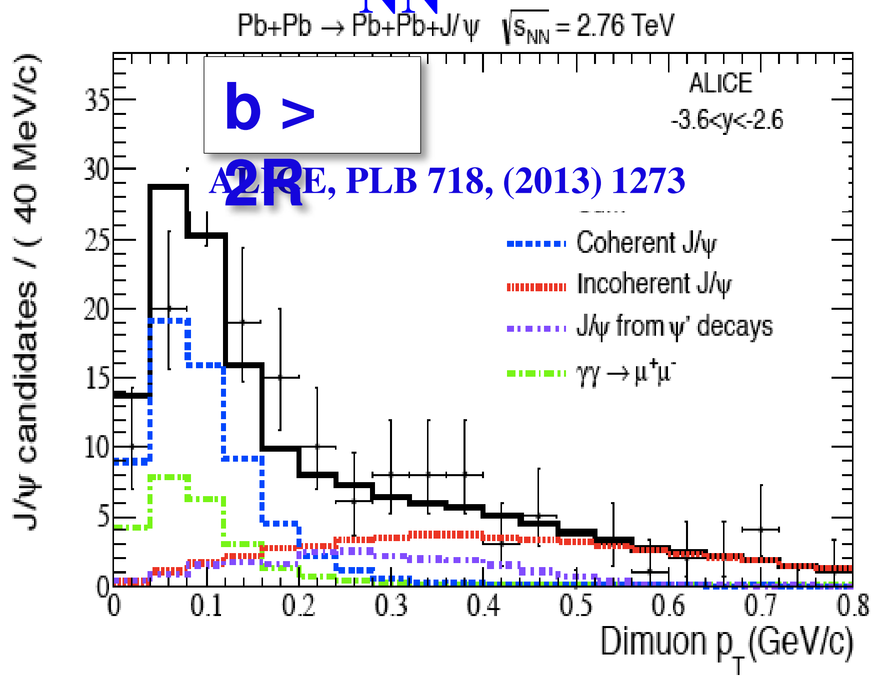


Избыточный выход в области малых p_T в периферийных Pb-Pb столкновениях

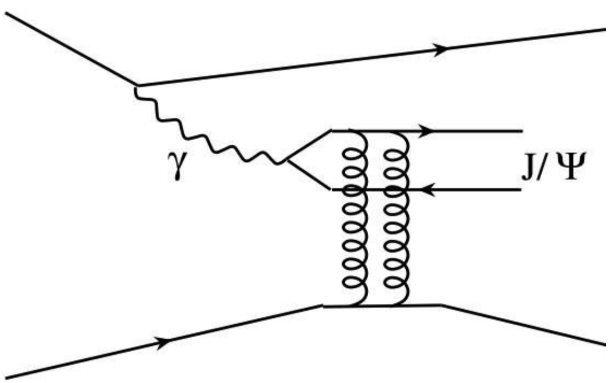
Избыток наблюдается в области p_T < 0.3 GeV/c

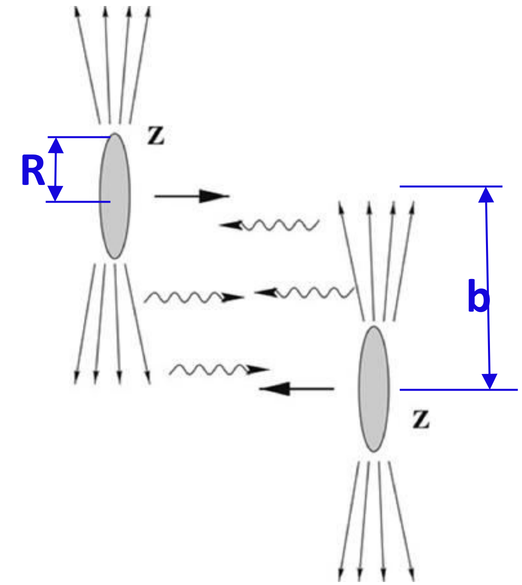
Избыточный выход J/Ψ, Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV



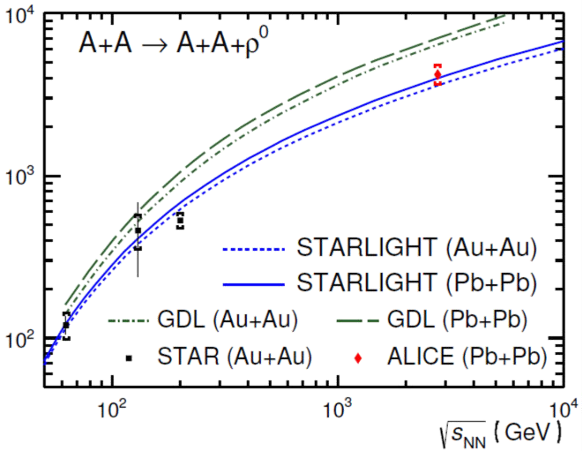


Качественно похоже на фоторождение J/ψ в ультра-периферических столкновениях (b>2R)

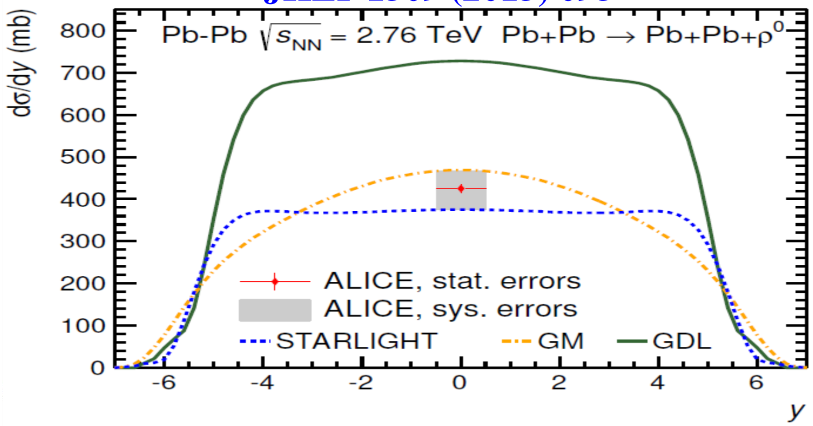




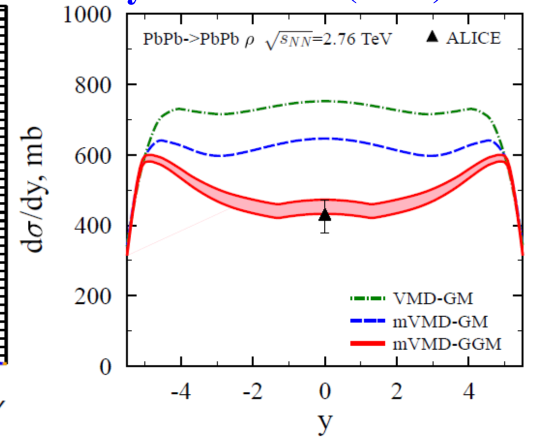
Фоторождение ρ, UPC Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV



JHEP 1509 (2015) 095



Phys.Lett. B752 (2016) 51-58



GDL: Frankfurt, Strikman, Zhalov [Phys. Lett. B 537 (2002) 51; Phys. Rev. C 67(2003) 034901]

- Vector Meson Dominance Model in the Gribov-Glauber approach.
- $\sigma_{\rho N}$ from Donnachie-Landshoff model.

GM: Gonçalves, Machado [Phys. Rev. C 84 (2011) 011902]

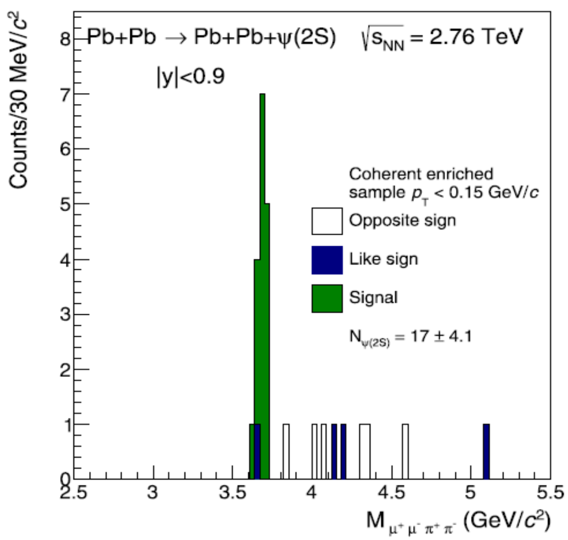
- Based on the color dipole model in combination with saturation from a CGC-IIM model.

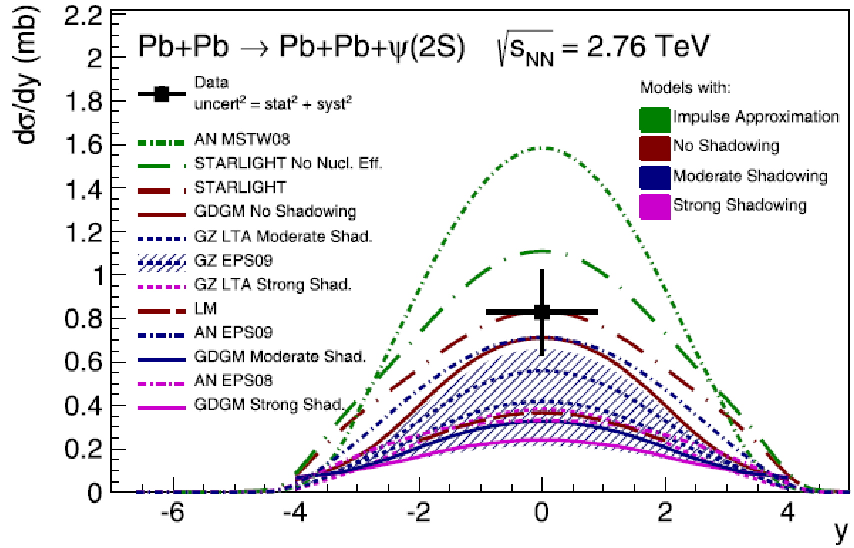
STARLIGHT: Klein, Nystrand [Phys. Rev. C 60 (1999) 014903, http://starlight.hepforge.org/]

- Glauber model neglecting the elastic part of total cross section.
- Uses experimental data on $\sigma_{\rho N}$ cross section.

Фоторождение Ψ', UPC Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV

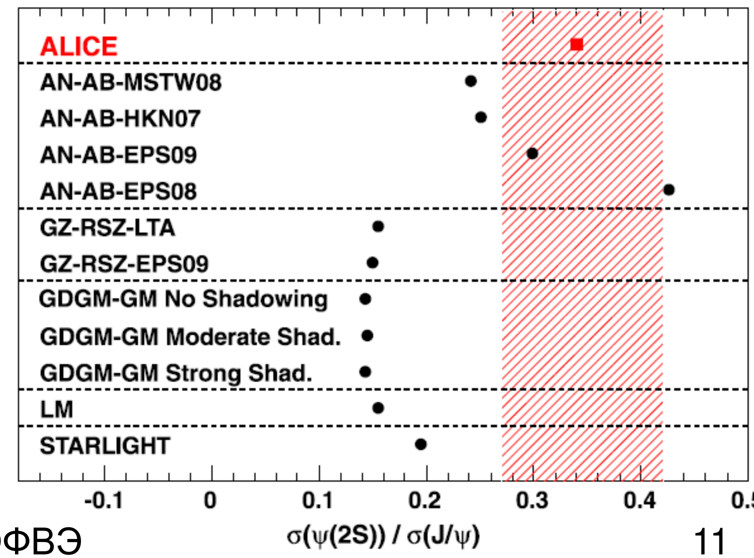
PLB751 (2015) 358



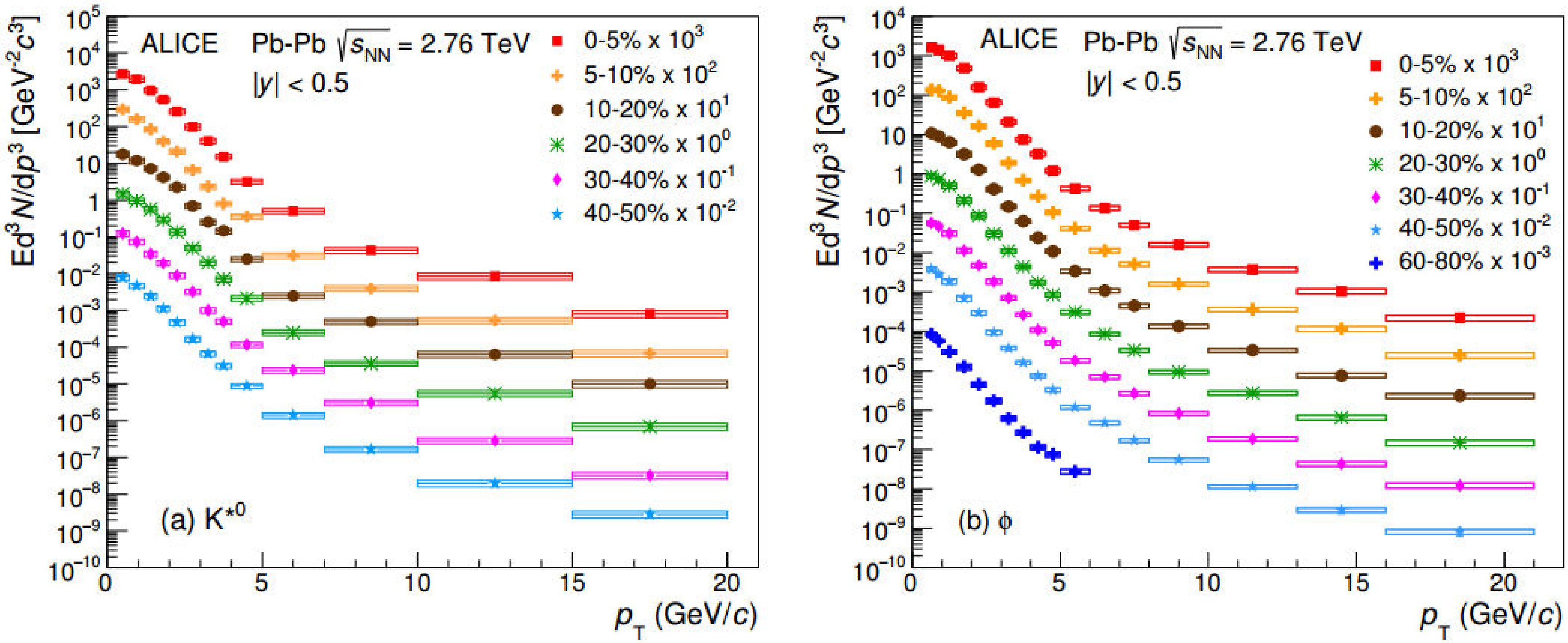


- Модели без ядерных эффектов или с сильной экранировкой глюонных плотностей плохо описывают данные
- Основные неопределенности связаны с неопределенностью γp сечения в теоретических расчетах
- Экспериментальные и теоретические неопределенности ы большой степени сокращаются в отношении **σ(ψ(2S))/σ(J/ψ)**
- Ядерные эффекты по разному влияют на 1S и 2S состояния?

$$(d\sigma^{coh}_{\psi(2S)}/dy)/(d\sigma^{coh}_{J/\psi}/dy) = 0.34^{+0.08}_{-0.07}(\text{stat} + \text{syst}).$$



K* и ϕ, Pb+Pb, $\sqrt{s_{NN}}$ = 2.76 ТэВ

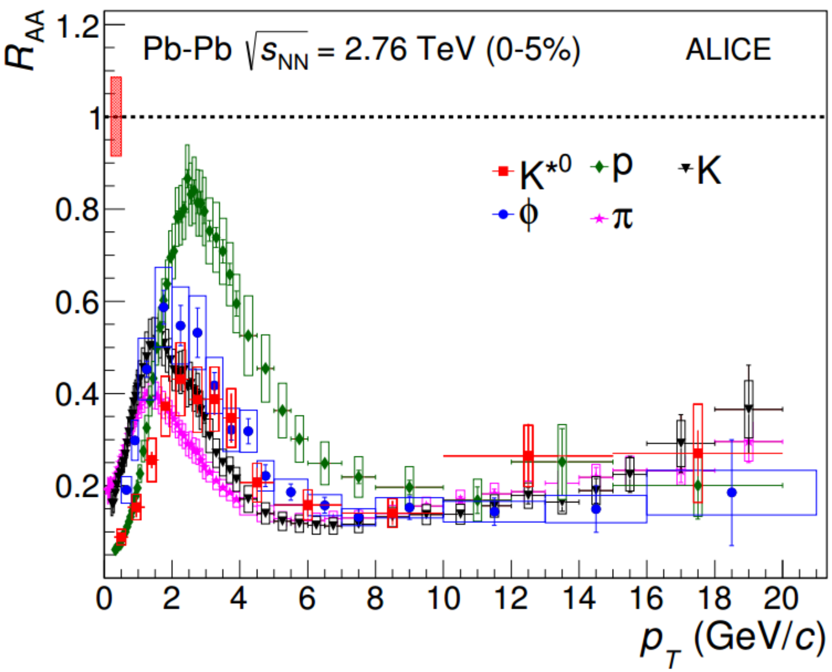


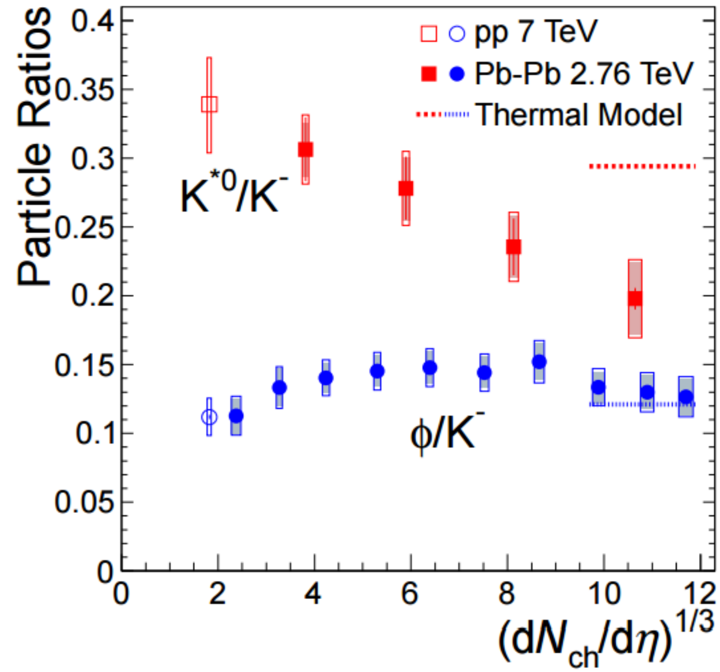
❖ Первые в мире измерения резонансов в широкой области поперечных импульсов до 20 ГэВ/с:

- ✓ p+p, p+Pb и Pb+Pb
- ✓ массы, ширины, отношения и т.д.

K* и ϕ, Pb+Pb, $\sqrt{s_{NN}}$ = 2.76 ТэВ

Phys.Rev. C91 (2015) 024609





❖ Выход всех идентифицированных адронов (π, K, p, K*, ϕ) одинаково подавлен в области больших поперечных импульсов

❖ Перерассеяние в адронной фазе существенно влияет на формы спектров рождения и измеренный выходы короткоживущих резонансов

❖ Время жизни адронной фазы > 5 фм/с

K* и ϕ, Pb+Pb, $\sqrt{s_{NN}}$ = 2.76 ТэВ

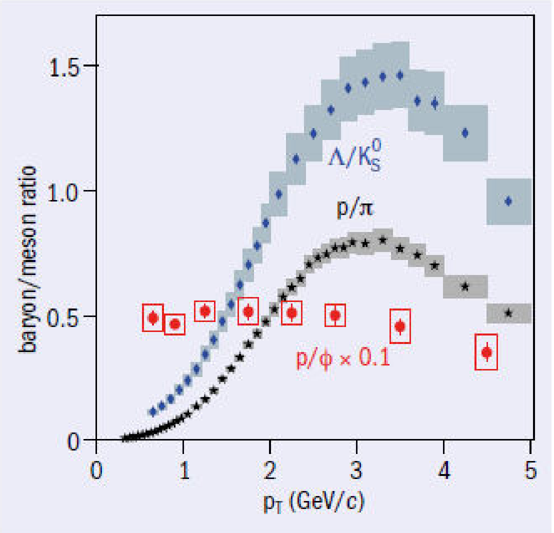
CERN Courier March 2015

News

ALICE sheds light on particle production in heavy-ion collisions

New results from the ALICE collaboration are providing additional data to test ideas about how particles are produced out of the quark–gluon plasma (QGP) created in heavy-ion collisions at the LHC.

Experiments at Brookhaven's Relativistic Heavy Ion Collider (RHIC) observed an enhancement in p_T-dependent baryon/meson ratios – specifically the p/π and Λ/K^0_S ratios – for central nucleus–nucleus (AA) collisions in comparison with proton–proton (pp) collisions, where particle production is assumed to be dominated by parton fragmentation. In addition, constituent-quark scaling was observed in the elliptic-flow parameter, v_2, measured in AA collisions. To interpret these observations, the final-state particles a common radial velocity independent of their mass, but a different momentum (hydrodynamic flow). The resulting blue shift in the p_T spectrum therefore scales with particle mass, and is observed as a rise in the p/π and Λ/K^0_S ratios at low p_T (see figure). In such a hydrodynamic description, particles with the same mass have p_T spectra with similar shapes, independent of their quark content. The particular shape of the baryon/meson ratio observed in AA collisions therefore reflects the relative importance of hydrodynamic flow, parton fragmentation and quark coalescence. However, for the p/π and Λ/K^0_S ratios, the particles in the numerator and denominator differ in both mass and (anti)quark content, so



The flat dependence on p_T of the p/ϕ ratio measured by ALICE for central lead–lead collisions, compared with the p/π and Λ/K^0_S ratios, indicates hydrodynamics as the leading contribution to the p_T spectra.

In contrast, as the figure shows, in central lead–lead collisions – where the volume of the QGP produced is largest – the p/ϕ

CPT инвариантность

nature physics

LETTERS

PUBLISHED ONLINE: 17 AUGUST 2015 | DOI: 10.1038/NPHYS3432

OPEN

Precision measurement of the mass difference between light nuclei and anti-nuclei

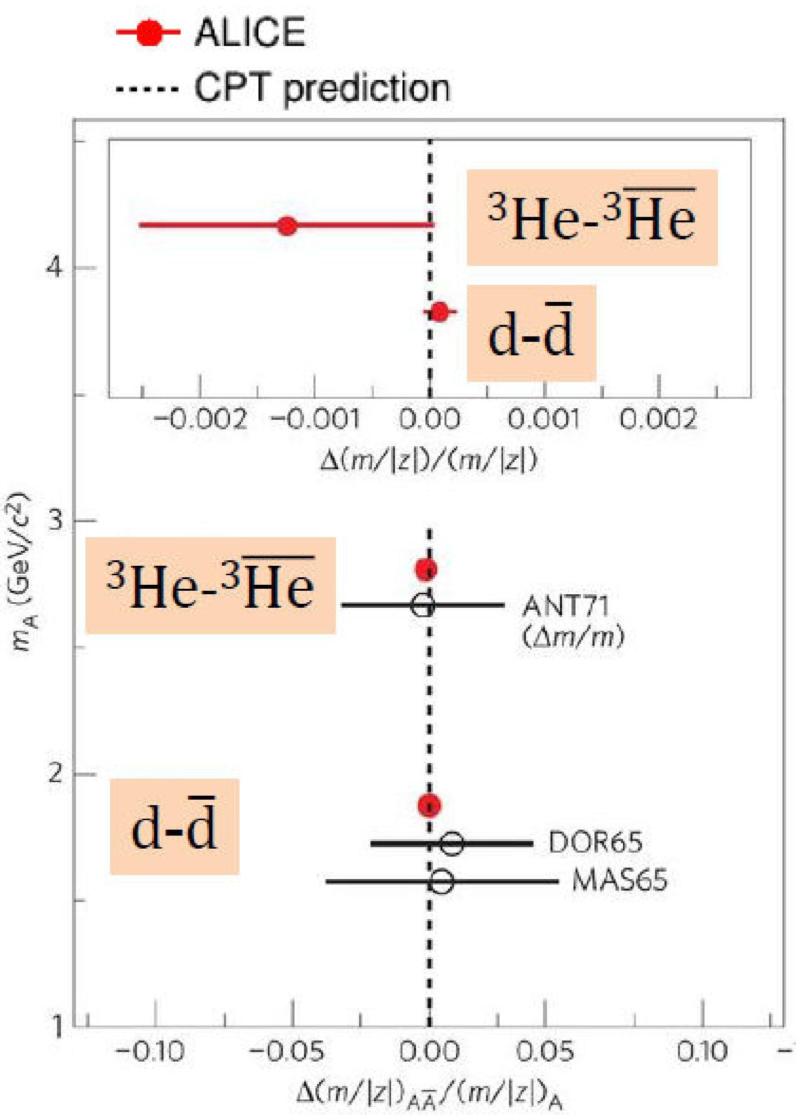
ALICE Collaboration†

The measurement of the mass differences for systems bound by the strong force has reached a very high precision with protons and anti-protons[1,2]. The extension of such measurement from (anti-)baryons to (anti-)nuclei allows one to probe any difference in the interactions between nucleons and anti-nucleons encoded in the (anti-)nuclei masses. This force is a remnant of the underlying strong interaction among quarks and gluons and can be described by effective theories[3], but cannot yet be directly derived from quantum chromodynamics. Here we report a measurement of the difference between the ratios of the mass and charge of deuterons (d) and anti-deuterons ($\bar{d}$), and ^{3}He and $^3\overline{\text{He}}$ nuclei carried out with the ALICE (A Large Ion Collider Experiment)[4] detector in Pb-Pb collisions at a centre-of-mass energy per nucleon pair of 2.76 TeV. Our direct measurement of the mass-over-charge differences confirms CPT invariance to an unprecedented precision in the sector of light nuclei[5,6]. This fundamental symmetry of nature, which

and specific energy loss (dE/dx) measurements, and the TOF (time of flight)[23] detector to measure the time t_{TOF} needed by each track to traverse the detector. The combined ITS and TPC information is used to determine the track length (L) and the rigidity (p/z, where p is the momentum and z the electric charge in units of the elementary charge e) of the charged particles in the solenoidal 0.5 T magnetic field of the ALICE central barrel (pseudo-rapidity $|\eta| < 0.8$). On the basis of these measurements, we can extract the squared mass-over-charge ratio $\mu^2_{TOF} \equiv (m/z)^2_{TOF} = (p/z)^2 [(t_{TOF}/L)^2 - 1/c^2]$. The choice of this variable is motivated by the fact that μ^2 is directly proportional to the square of the time of flight, allowing to better preserve its Gaussian behaviour.

The high precision of the TOF detector, which determines the arrival time of the particle with a resolution of 80 ps (ref. 20), allows us to measure a clear signal for (anti-)protons, (anti-)deuterons and (anti-)^{3}He nuclei over a wide rigidity range ($1 < p/|z| < 4$ GeV/c). The main source of background, which is potentially of the same

Относительная разница масс: d, ^{3}He



$$\frac{\Delta\mu_{d\bar{d}}}{\mu_d} = (0.9 \pm 0.5(\text{stat.}) \pm 1.4(\text{syst.})) \times 10^{-4}$$

$$\frac{\Delta\mu_{^3\text{He}^3\overline{\text{He}}}}{\mu_{^3\text{He}}} = (-1.2 \pm 0.9(\text{stat.}) \pm 1.0(\text{syst.})) \times 10^{-3}$$

Highest precision direct measurements of mass difference **in the sector of nuclei**

Improvement by one to two orders of magnitude compared to previous measurements obtained more than 40 years ago

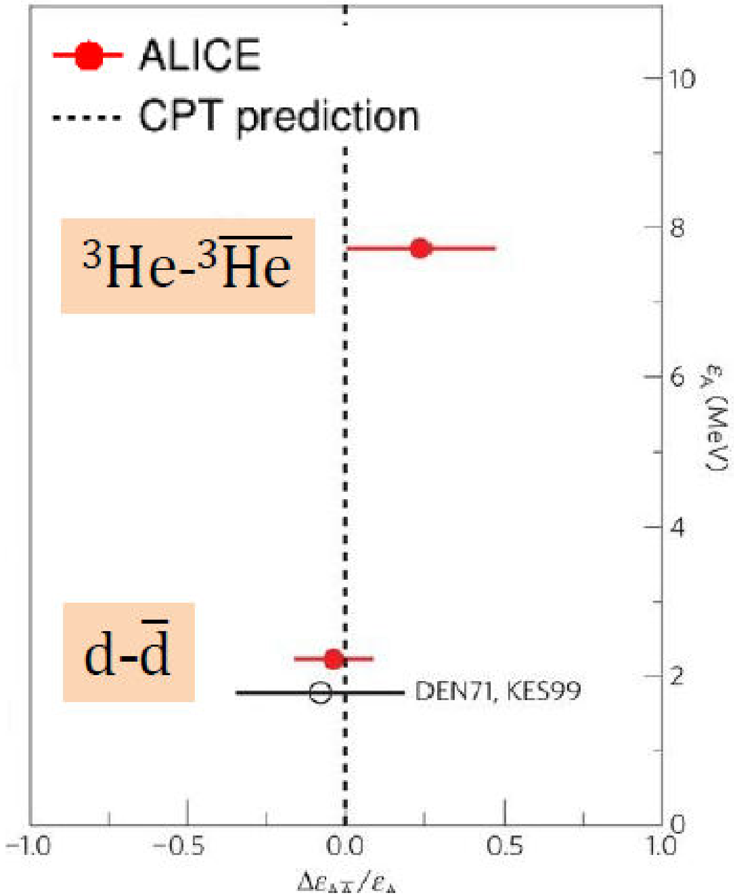
ANT71: Nucl. Phys. B31 (1971) 235
DOR65: PRL 14 (1965) 1003
MAS65: Nuovo Cim. 39 (1965) 10

Энергия связи: d, ^{3}He

$$\Delta\varepsilon_{A\bar{A}} = Z\Delta m_{p\bar{p}} + (A-Z)\Delta m_{n\bar{n}} - \Delta m_{A\bar{A}}$$

$\Delta m_{p\bar{p}} < 7 \times 10^{-10}$ GeV/c^2 (CL = 90%) ← Nature 574 (2011) 484

$\Delta m_{n\bar{n}} = 0.85 \pm 0.51(\text{stat}) \pm 0.29(\text{syst}) \times 10^{-4}$ GeV/c^2 ← PLB 177 (1986) 206



$$\frac{\Delta\varepsilon_{d\bar{d}}}{\varepsilon_d} = -0.04 \pm 0.05\ (\text{stat.}) \pm 0.12\ (\text{syst.})$$

$$\frac{\Delta\varepsilon_{^3\text{He}^3\overline{\text{He}}}}{\varepsilon_{^3\text{He}}} = 0.24 \pm 0.16\ (\text{stat.}) \pm 0.18\ (\text{syst.})$$

- Constraint on CPT symmetry violation improved by a **factor two for (anti-)deuteron case**
- $\Delta\varepsilon$ determined for the **first time in case of (anti-)^{3}He**

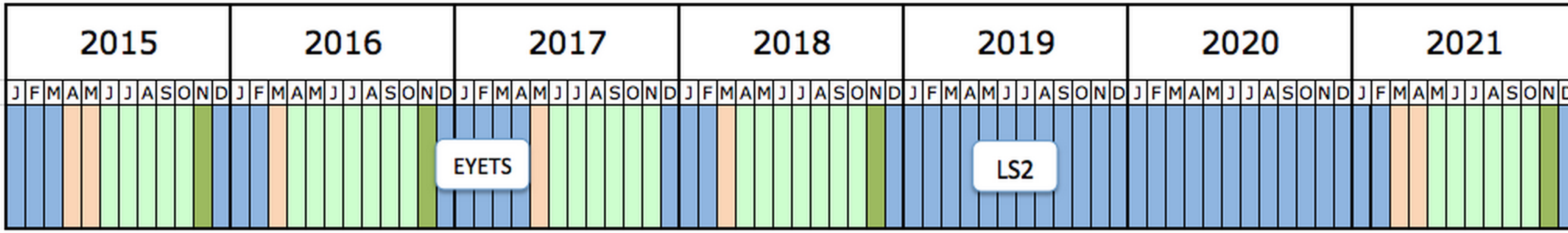
ALICE: Nature Physics 2015
DEN71: Nucl. Phys. B31 (1971) 253
KES99: Phys.Lett. A255 (1999) 221

Заключение

- Продолжается успешное участие в эксперименте ALICE:
  - поддержка детекторов, набор данных и смены
  - физический анализ данных
  - подготовка публикаций
  - планируем защиту к/д в первой половине 2016 (М.В. Малаев)

BACKUP

Run-II, plans



Year	System	E [TeV]	Lumi [cm^{-2}s^{-1}]	Rate [kHz]	Time*
2015	pp	13	5×10^{30}	300	7w
	PbPb	5.02	1×10^{27}	8	3w
	pp-ref	5.02	5×10^{30}	300	4d
2016	pp	13	5×10^{30}	300	28w
	pPb (2018?)	5.02	1×10^{29}	200	4w
	pp-ref	5.02	5×10^{30}	300	7d
2017	pp	13	5×10^{30}	300	24w
2018	Pp	13	5×10^{30}	300	28w
	PbPb (2016?)	5.02	1×10^{27}	8	4w
	pp-ref	5.02	5×10^{30}	300	7d