

INTERNATIONAL MASTERCLASSES HANDS ON PARTICLE PHYSICS

Masterclasses: Warsztaty z fizyki cząstek PODSUMOWANIE WYNIKÓW

Politechnika Warszawska



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Wzmocnienie dziwności

Wzmocnienie dziwności = sygnatura plazmy kwarkowo-gluonowej.

Teoretycy twierdzą, że więcej cząstek dziwnych powinno powstawać w zderzeniach ciężkich jonów (podzielonych przez liczbę zderzeń elementarnych), gdzie powstaje plazma kwarkowo-gluonowa, niż w zderzeniach proton-proton.

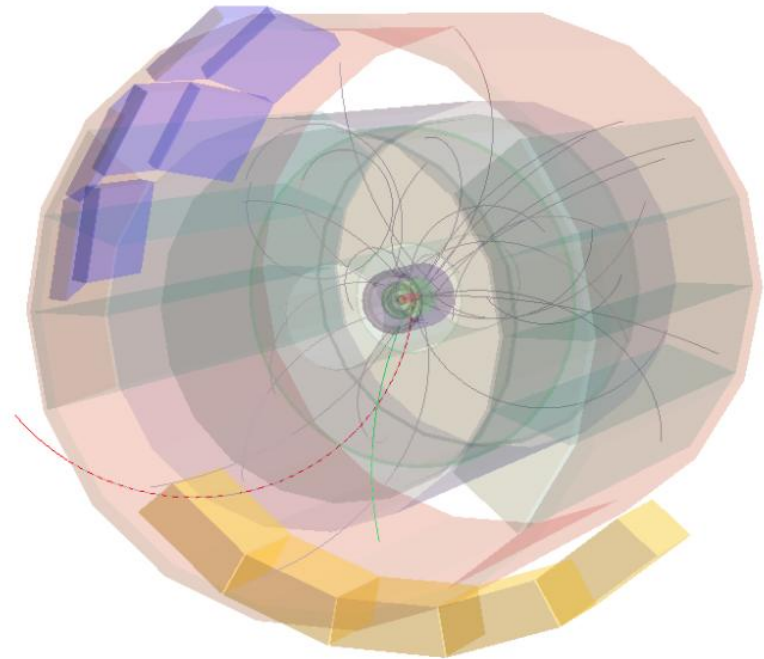
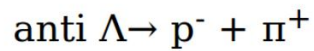
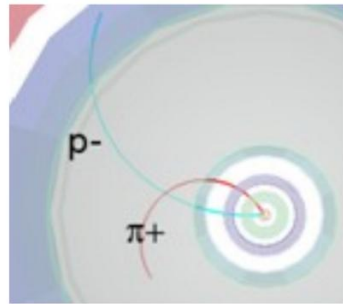
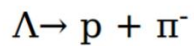
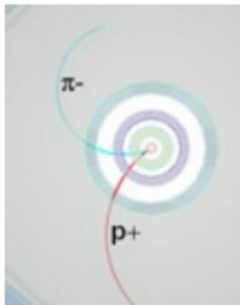
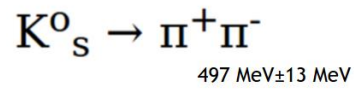
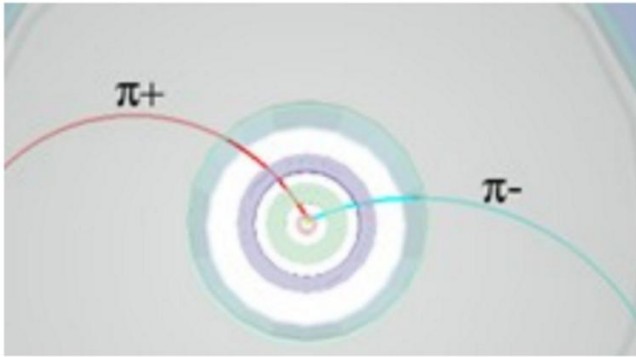
Jak sprawdzić? **Policzyć cząstki dziwne zarówno w zderzeniach ołów-ołów jak i proton-proton.**



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Analiza wizualna



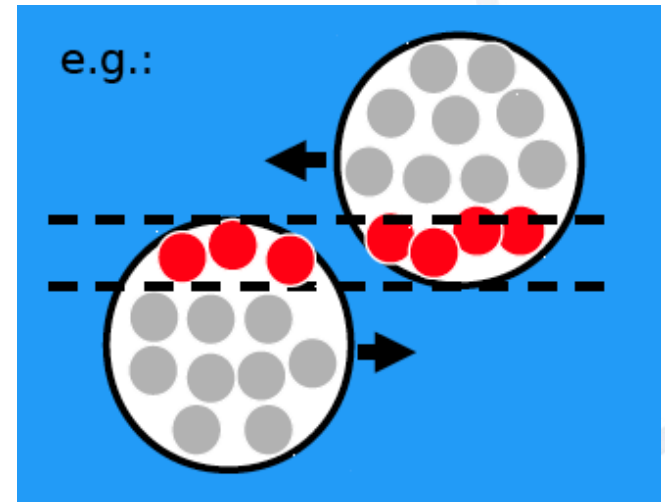
Use of Event Display at the Control Room



2009/11/23

Analiza Pb-Pb w binach centralności

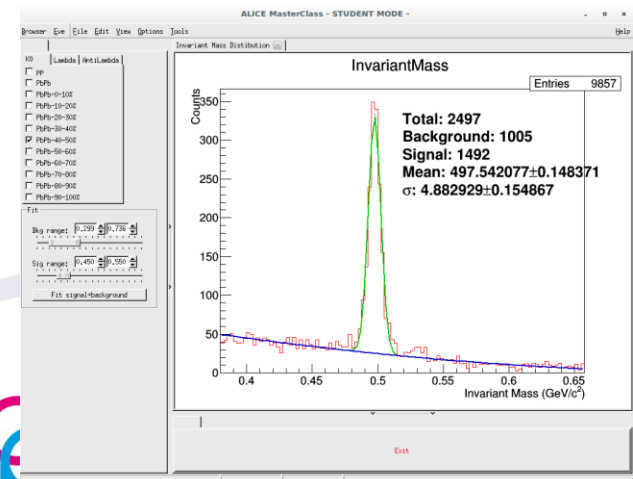
- „Wysoka statystyka”
- Dopasowujemy tło (funkcja kwadratowa)
- Dopasowujemy sygnał (Gauss)
- Szukamy liczby cząstek dziwnych:
wynik = sygnał - tło
- Różne zespoły analizują różne centralności



Analiza Pb-Pb

40 naukowców:

- analizowano kaony, lambdy, antilambdy
- dla centralności 0 – 80%
- wynik: średnia ze wszystkich wyników



centrality	<Npart>	Nevents	NKs	efficiency Ks	yield Ks	Ks enhancem
0-10	360	213		0.26	86.963	1.933
10-20	260	290		0.26	61.512	1.893
20-30	186	302		0.29	42.818	1.842
30-40	129	310		0.29	29.032	1.800
40-50	85	302		0.29	17.047	1.604
50-60	52	300		0.29	8.931	1.374
60-70	30	315		0.35	3.710	0.989
70-80	16	350		0.26	1.637	0.819

$$\text{Wydajność (efficiency)} = N_{\text{cząstek (zmierzonych)}} / N_{\text{cząstek (wyprodukowanych)}}^*$$

*wartości wydajności : uzyskane z wyników badań przeprowadzonych przez eksperyment

Uzysk : liczba cząstek wyprodukowanych w pojedynczym zderzeniu

$$\text{Uzysk (yield)} = N_{\text{cząstek (wyprodukowanych)}} / N_{\text{events}} = N_{\text{cząstek (zmierzonych)}} / (\text{wydajność} \times N_{\text{zderzeń}})$$

Wzmocnienie dziwności (enhancement): uzysk cząstek dziwnych podzielony przez liczbę nukleonów partycypujących w zderzeniu oraz przez uzysk cząstek dziwnych w zderzeniach proton-proton*.

$$\text{Uzysk } K_s \text{ (pp)} = 0.25 \text{ /zderzenie} ; \text{ Uzysk } \Lambda \text{ (pp)} = 0.0617 \text{ /zderzenie} ; \langle N_{\text{part}} \rangle = 2 \text{ dla pp}$$

*Uzysk w pp dla 2.76 TeV na podstawie interpolacji wyników z 900 GeV i 7 TeV



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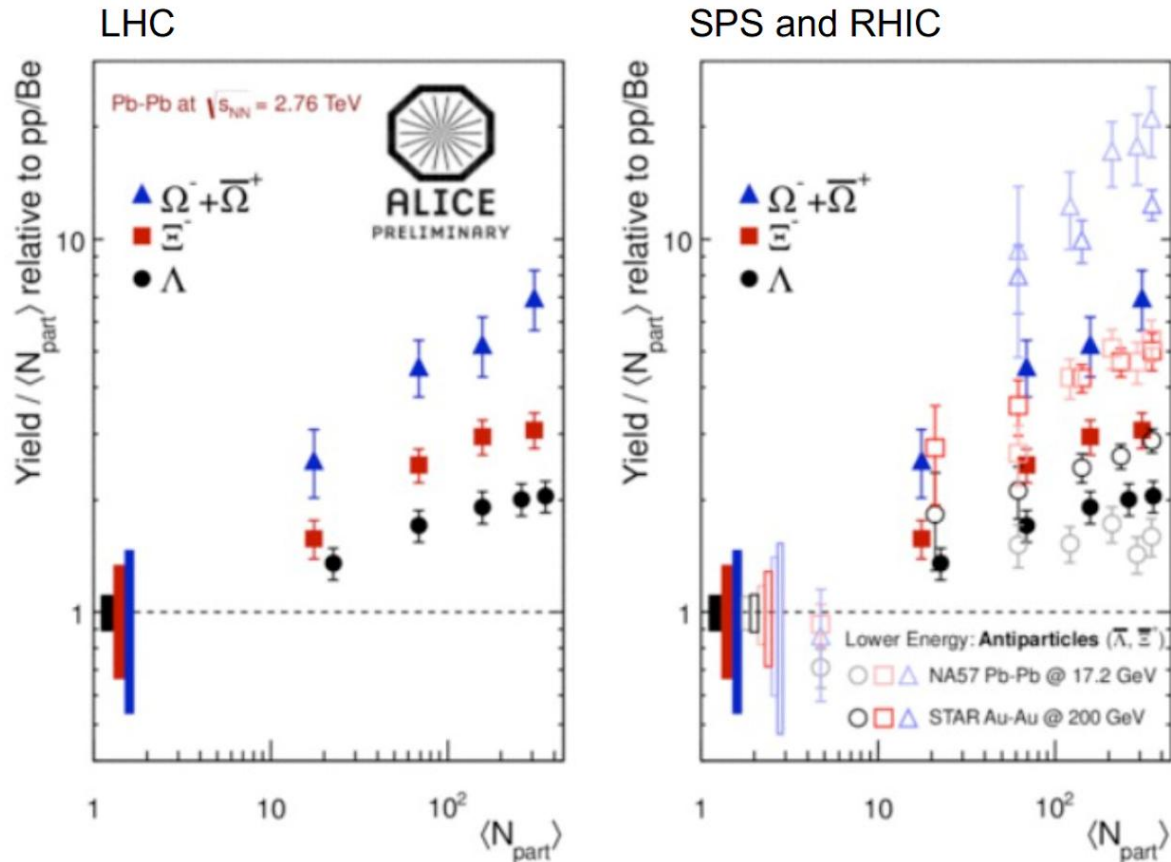
Analiza Pb-Pb

Wykres wzmocnienia dziwności

→ <https://teacher-alice-web-masterclass.app.cern.ch/>

„Strangeness enhancement plot”

Particle yield per participant normalised to reference



ALI-PREL-43394



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Wynik

Zaobserwowano wzmocnienie dziwności, sygnaturę plazmy kwarkowo-gluonowej w zderzeniach ołów-ołów zarejestrowanych przez eksperyment ALICE.

Czas na wideokonferencję

Czy macie jakieś pytania
do ekspertów z CERN?

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Each year over 13,000 high school students from 60 countries step out of the classroom for a day to immerse themselves in the fascinating world of Quarks and Leptons. Hosted by 225 universities and research centres, these masterclasses offer a unique chance to unravel the mysteries of matter and forces, enabling the students to perform measurements on real data from particle physics experiments themselves. At the end of each day, like in an international research collaboration, the participants join in a video conference for discussion and combination of their results. International Masterclasses aren't just events; they're a passport to discovery, an annual opportunity for 15- to 19-year-old students to ignite their curiosity in particle physics. International Masterclasses promise to make science come alive in a way that textbooks never could. Get ready to go beyond the classroom and into the forefront of scientific exploration!

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Strangeness as QGP signature

Strangeness: A signature of QGP and Deconfinement

In order to observe properties of quark-gluon plasma we must design a thermometer, an isolated degree of freedom weakly coupled to the hadronic matter. Nature has, in principle (but not in praxis) provided several such thermometers: leptons and heavy flavours of quarks. We would like to point here to a particular phenomenon perhaps quite uniquely characteristic of quark matter; first we note that, at a given temperature, the quark-gluon plasma will contain an equal number of strange (s) quarks and antistrange (\bar{s}) quarks, naturally assuming that the hadronic collision time is much too short to allow for light flavour weak interaction conversion to strangeness. Thus, assuming equilibrium in the quark plasma, we find the density of the strange quarks to be (two spins and three colours):

$$\frac{s}{V} = \frac{\bar{s}}{V} = 6 \int \frac{d^3p}{(2\pi)^3} e^{-\sqrt{p^2 + m_s^2}/T} = 3 \frac{T m_s^2}{\pi^2} K_2\left(\frac{m_s}{T}\right) \quad (26)$$

(neglecting, for the time being, the perturbative corrections and, of course, ignoring weak decays). As the mass of the strange quarks, m_s , in the perturbative vacuum is believed to be of the order of 280-300 MeV, the assumption of equilibrium for $m_s/T \sim 2$ may indeed be correct. In Eq. (26) we were able to use the Boltzmann distribution again, as the density of strangeness is relatively low. Similarly, there is a certain light antiquark density (\bar{q} stands for either \bar{u} or \bar{d}):

$$\frac{\bar{q}}{V} \approx 6 \int \frac{d^3p}{(2\pi)^3} e^{-|p|/T - \mu_q/T} = e^{-\mu_q/T} \cdot T^3 \frac{6}{\pi^2} \quad (27)$$

where the quark chemical potential is, as given by Eq. (3), $\mu_q = \mu/3$. This exponent suppresses the $q\bar{q}$ pair production as only for energies higher than μ_q is there a large number of empty states available for the q .

What we intend to show is that there are many more \bar{s} quarks than antiquarks of each light flavour. Indeed:

$$\frac{\bar{s}}{\bar{q}} = \frac{1}{2} \left(\frac{m_s}{T}\right)^2 K_2\left(\frac{m_s}{T}\right) e^{\mu/3T} \quad (28)$$

The function $x^2 K_2(x)$ is, for example, tabulated in Ref. 15). For $x = m_s/T$ between 1.5 and 2, it varies between 1.3 and 1. Thus, we almost always have more \bar{s} than \bar{q} quarks and, in many cases of interest, $\bar{s}/\bar{q} \sim 5$. As $\mu \rightarrow 0$ there are about as many \bar{u} and \bar{d} quarks as there are \bar{s} quarks.



J. R. & R. Hagedorn, CERN-TH-2969, Oct.1980
From Hadron gas to Quark Matter

$\bar{s}/\bar{q} \rightarrow K^+/\pi^+$, and strange antibaryons $\bar{s}/\bar{q} \rightarrow \bar{\Lambda}/p$ are proposed as signatures of deconfined QGP phase, matter-antimatter symmetry.

Chemical equilibrium in QGP is presumed in the argument.

From SQM11: Strangeness in Quark Matter, 2011, Kraków, Poland



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Strangeness in Quark Matter, SQM 2011

From SQM11: Strangeness in Quark Matter, 2011, Kraków, Poland



Berndt Müller

Jan Rafelski

J Rafelski, B. Muller, Phys. Rev. Lett. 48:1066 (1982)



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Experimental observations

At SPS by:

- WA85 in S-Pb & Pb-Pb collisions
- NA35 in S-S & Pb-Pb collisions

J. Rafelski, Arizona

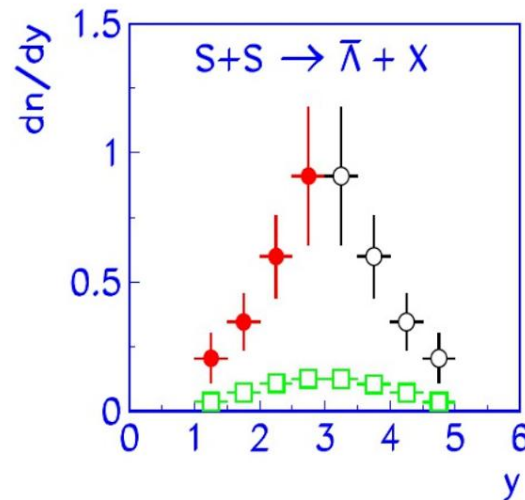
Strangeness QGP

September 22, 2011, SQM2011

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Central Rapidity Fireball and QGP



First antibaryon enhancement result, 1990-94, SPS-NA35II EXCESS $\bar{\Lambda}$ emitted from a central well localized source. Background (squares) from multiplicity scaled NN reactions. From **Yiota Foka**, PhD Thesis, Geneva University 1994.



Conclusion: by early 1990's we have convincing evidence of QGP formation at SPS energy heavy ion collisions including S-S.

From SQM11: Strangeness in Quark Matter, 2011, Kraków, Poland



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