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GROWTH POINTS OF NUCLEAR PHYSICS *

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The XXVII. Mazurian Lakes School of Physics was mainly devoted to four different topics:

(i) Medium modifications of the nucleon–nucleon interaction and the nucleon–nucleon cross-section, medium dependence of hadrons masses and the equation of state of nuclear matter studied in heavy ion collisions.

(ii) Nuclear astrophysics with a special emphasis on cosmic ray's.

(iii) New developments in neutrino physics.

(iv) Future plans for the GSI in Darmstadt and the first results from RHIC in Brookhaven.

I have to excuse, but I will due to time reasons not summarise the shorter evening seminars and I will only shortly mention the talks of this Saturday morning.

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1. In-medium modifications of the nucleon–nucleon interaction and the nuclear Equation Of State (EOS)

Under this heading one can summarize the talks of Paweł Danielewicz about the in-medium modifications of the nucleon-nucleon interaction and the effective nucleon mass, the talk of Willi Reisdorf about the proton flux in heavy ion reaction measured by FOPI at GSI, the talk of Wim Dickhoff about dressed single particle states and the equation of state, the talk of Hermann Wolter about the isospin dependence of the equation of state and about isospin destilation, the talk of Wolfram von Oertzen about the density dependence of the nucleon–nucleon interaction and the equation of state determined by the collision between two ^{16}O nuclei, the talk of

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Bogusław Zwięgliński about the liquid-gas phase transition, the talk of Bruce Barett about no core shell model calculations for light nuclei and the effective nucleon–nucleon interaction and finally the talk of Peter Butler on new experimental results on properties of heavy nuclei like Nobelium 254.

Paweł Danielewicz from the Michigan State University reminded us of two well-known facts:

(i) The nucleon–nucleon interaction and by that also the nucleon–nucleon cross-section is smaller in nuclear matter than in the vacuum. This is due to Pauli blocking of the intermediate states, when one is summing up the ladder diagrams to determine the effective nucleon–nucleon interaction. This means that the meanfree path for nucleons in nuclear matter is larger.

(ii) The effective mass of the nucleons are reduced in nuclear matter. Around saturation density $\rho_0 = 0.17$ nucleons/fm^3 one expects:

$$m_N^*(\rho_0) \approx 0.7 m_N^{\mathrm{free}} \tag{1}$$

by the reduction of the effective mass the velocity of the nucleons is increasing for the same momentum.

He discussed observables to see in heavy ion collisions these two effects. His answer was the azimuthal (angle ϕ) focusing of the proton flux. As the relevant observable, he defined the azimuthal asymmetry:

$$R_N = \frac{N(90^\circ) + N(270^\circ)}{N(0^\circ) + N(180^\circ)}\,. \tag{2}$$

The azimuthal angle $\phi = 0^\circ$ and $\phi = 180^\circ$ are in the reaction plane while $N(90^\circ)$ and $N(270^\circ)$ give the number of protons squeezed out perpendicular to the reaction plane.

He considered the reaction Bi on Bi with 400 MeV per nucleon and simulated this heavy ion reaction with his Boltzmann–Uehling–Uhlenbeck code.

What does one expect: The reduction of the nucleon–nucleon interaction increases the mean-free path of the hot protons from the fireball through the two spectators and by that the asymmetry R_N should be reduced especially for protons with high momenta perpendicular to the beam direction. The reduction of the effective mass $m*$ is increasing the velocity of the protons which try to escape from the fire ball. Due to their increased speed, they try to escape while the projectile and the target spectators are still shadowing the fireball. By that the azimuthal asymmetry is increasing.

Paweł Danielewicz found in his simulations of the Bi–Bi heavy ion reaction exactly this behaviour. To get agreement with the data from KAOS he had to decrease the mass of the nucleon by a factor 0.7 as expected and he had slightly only to decrease the in-medium nucleon–nucleon cross-section compared to the free one. Presently the decrease of the effective mass and the decrease of the free nucleon–nucleon cross-section in nuclear matter are fits to the data. Brueckner calculation or investigations within the Walecka model should be able to derive from first principles these reductions.

Peter Senger from the KAOS collaboration at GSI used also the azimuthal focusing, but for K^+ mesons and not for protons.

Figure 1 shows that the interaction of K^+ mesons is repulsive in nuclear matter and thus the effective mass is increasing as a function of the nuclear matter density. We expect therefore that the azimuthal asymmetry is increasing if one includes this repulsive effect.

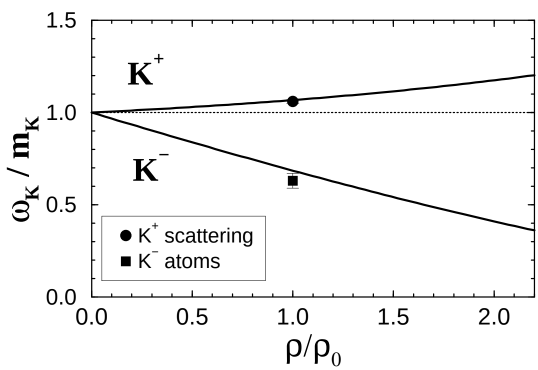

Fig. 1. The effective masses of K^+ and K^- mesons as a function of density in nuclear matter as predicted by several K–nucleon interaction models.

Figure 2 shows the data from the KAOS collaboration compared with calculations from the Tuebingen group. Without including the repulsive K^+-nucleon potential, one obtains a rather flat curve which cannot describe the data while the inclusion of the Kaon nucleon interaction gives a much larger asymmetry (maxima at $\phi = 90°$ and $\phi = -90° = 270°$).

Wim Dickhoff spoke about dressed single particle states and the nuclear equation of state EOS. Figure 3 shows the energy per nucleon as a function of the Fermi momentum which is closely connected with the density of nuclear matter. A typical Brueckner–Hartree–Fock calculation misses the experimental point given in figure 3. Different realistic nucleon–nucleon interactions give values on the Coester band, which misses the experimental value. In the last 20 years different groups tried to reproduce the correct experimental saturation density and binding energy by including density de-

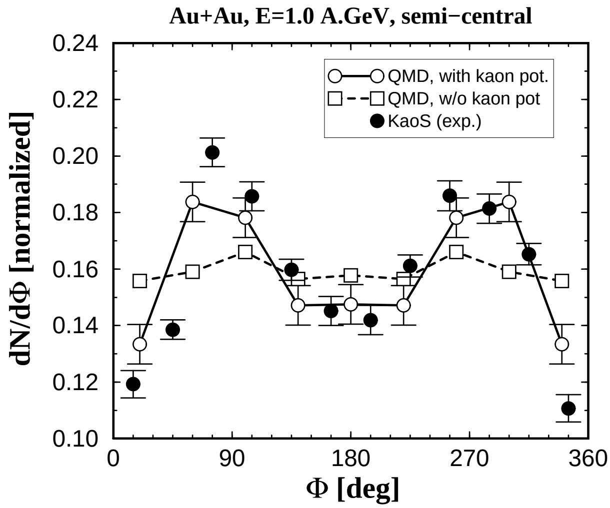

Fig. 2. Azimuthal distribution of the K^+ mesons in a $An + AnE = 1A$GeV semi-central reaction. The blackdots are the experimental data from Kaos. the circles connected by a solid line are the theoretical QMD results of the Tuebingen group with the K^+_- nucleus potential, while the squares are QMD results without a K^+_- nucleus potential.

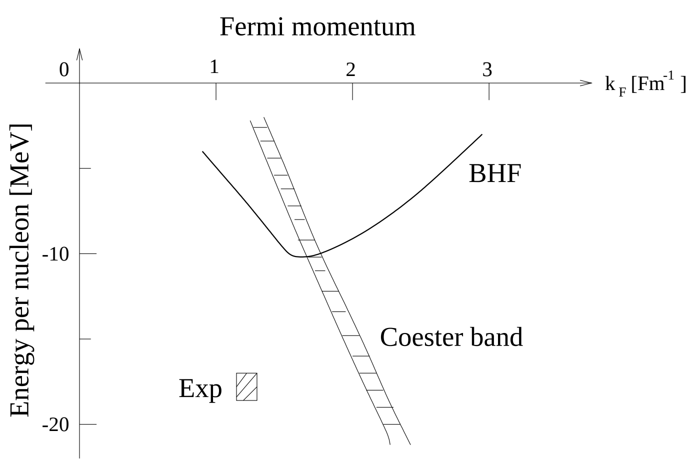

Fig. 3. Energy per nucleon as a function of the Fermi momentum $k_{\mathrm{F}} = \left[\frac{3\pi^2}{2}\rho\right]^{1/3}$. The saturation value from heavy nuclei is $k_{\mathrm{F}} = 1.33\ \mathrm{fm}^{-1}$. The binding energy per nucleon in nuclear matter $E/A \approx -16$ MeV is extracted from the Weizsäcker mass formula.

pendence in the nucleon–nucleon interaction and relativistic effects. It seems possible especially by careful inclusion of relativistic effects to describe correctly the experimental point in figure three. Wim Dickhoff went an other way. He pointed out that the notion of single particle states, for example in a Brueckner–Hartree–Fock calculation does not correspond to experiment. Single particle states are dressed by particle hole excitations due to short range and long range correlations.

He dressed the single particle states by the short range correlations as shown in figure 4 by solving the Dyson equation for dressed particles and by obtaining the effective interaction due to the solution of a generalised Bethe–Goldstone equation with dressed particles. He calculated the total binding energy at $k_{\mathrm{F}} = 1.36$ and $k_{\mathrm{F}} = 1.45\ \mathrm{fm}^{-1}$. At the Fermi momentum $k_{\mathrm{F}} = 1.36\ \mathrm{fm}^{-1}$ he obtained a good agreement with the experimental value in figure 3. The binding energy per nucleon at $k_{\mathrm{F}} = 1.45\ \mathrm{fm}^{-1}$ lies higher if included in figure 3 and thus indicates saturation in the direction to higher densities. One naturally would like to have also a point at a density below the saturation density $k_{\mathrm{F}} \cong 1.33\ \mathrm{fm}^{-1}$ to see that one is indeed reaching the minimum at the right place. Further questions are inclusion of relativistic effects and inclusion of Delta and pionic degrees of freedom. He gave some qualitative hints that these effects should not be important in finite nuclei, but one must show it by including them into the calculation.

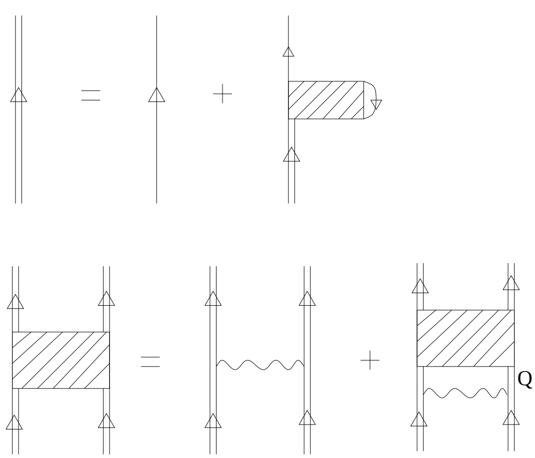

Fig. 4. Dyson equation and the generalised Bethe–Goldstone equation for dressed particles. The solution of the Dyson equation for dressing the particles needs the effective interaction, which needs to know the structure of the dressed particles (double selfconsistency).

Hermann Wolter studied in his talk the isospin dependence of the equation of state of nuclear matter. It is well-known that the pure neutron matter does not lead to a final stable nucleus. Neutron stars are only stable due to the large attractive gravitational force. He also investigated what happens if the density of nuclear matter is getting smaller: like with water one does not obtain a liquid with half the density, but the liquid is forming droplets. Nuclear matter is fragmenting, one speaks of the sinodal instability. If the neutron number is larger than the proton number, the formation of droplets leads to an isospin fractionisation. During the fragmentation of such asymmetric nuclear matte, one forms droplets of about the saturation density with an almost equal number of protons and neutrons. In this way one gains the largest binding energy. The remaining neutrons form a very low density neutron gas. This "isospin destillation" minimizes the total energy.

Hermann Wolter showed that in the highly asymmetric collision of Sn^{124} on Sn^{124} with $Z/N = 50/64 \cong 0.78$ one formed fragments with Z/N approaching unity and free neutrons.

The biggest isospin distillation happened during the nucleosynthesis in the big bang. After the temperature was reduced to below the binding energy of the deuteron, the weak interaction had produced due to the heavier mass of the neutrons about 7 times as many protons than neutrons. Thus for each 14 protons one had 2 neutrons. Due to isospin distillation 2 neutrons and 2 protons formed ^{4}He and 12 protons remained in a low-density proton gas. In this way 75 % of the hadron masses was in the form of protons and later as hydrogen and 15 % in the form of helium.

2. Nuclear astrophysics (cosmic rays)

In this field one can summarise the talk of Hendrik Schatz about X-ray bursts. He described the system of a binary star, where one is a neutron star in an accretion disk, where the large star pours hydrogen and helium gas into the disc, which due to internal friction is then continuously falling onto the surface of the neutron star. This leads to a sequence of proton capture reactions on and near the surface of the neutron star, which form neutron rich nuclei. To understand quantitatively what happens, one has to measure in the laboratory proton reactions on proton rich radioactive nuclei. He proposed that this is done in inverse kinematics using proton rich radioactive beams on a proton target.

Michael Hass studied the reaction

$$^{7}\mathrm{Be}\ (p,\gamma)\ ^{8}\mathrm{B} \tag{3}$$

which is responsible for the relative intensity of the ^{7}Be neutrinos in two discrete lines at 860 and 380 keV and the ^{8}B neutrinos which are contained in a continuum up to 14.6 Mev.

$$\begin{aligned}
{}^7\mathrm{Be} + e^- &\rightarrow {}^7\mathrm{Li} + \nu_e \;(860 + 380\mathrm{keV})\,, \\
{}^7\mathrm{Be} + p &\rightarrow {}^8\mathrm{B} + \gamma\,, \\
{}^8\mathrm{Be} &\rightarrow {}^8\mathrm{Be} + e^- + \nu_e\,. \qquad (4)
\end{aligned}$$

Heinigerd Rebel, Iliana Brancus and Tadeusz Wibig reported about cosmic rays.

Zbigniew Włodarczyk spoke about strangelets which could be candidates for the extreme high energy events of cosmic rays.

Eric Sheldon gave in his talk a very nice summary about the status of the determination of Hubble constant and due to time constraints he could only shortly indicate new results about Nucleochronology.

Heinigerd Rebel reported results from the KASKADE collaboration in Karlsruhe under the title: "Anatomy of the knee".

The intensity of the cosmic radiation per unit energy interval is falling off by a power law $E^{-2.7}$ up to an energy of about 5×10^6 GeV. Above this energy it is falling steeper with E^{-3} up to the so called angle around 5×10^9 GeV. The most energy rich events of cosmic radiations have been measured around 3×10^{20} eV to 3×10^{11} GeV by the AGASA collaboration in Akeno.

The main result of KASKADE as reported by Heinigerd Rebel is, that the knee is due to the light (mainly proton) component in the cosmic radiation, while the heavy (iron) component does not show a knee. This is explained by the fact that protons have at the same energy, but a larger speed than Fe and thus can escape above the knee from our galaxy. Especially hard to understand are the highest energies of cosmic ray events around 3×10^{20} eV. Such events are extremely seldom, but they exist. Events around 10^{19} eV occur at a rate of one per km^2 per year. At energies higher than about 5×10^{19} eV photons in the cosmic background radiation (2.7 Kelvin) have in the rest frame of the proton an energy above 300 MeV. Thus the collision with these high energy protons can produce pions. In this way the high energy protons should lose energy. The critical energy is the Greisen–Satsepin cut-off at around 5×10^{19} eV. Above this energy high energy protons should not exist for longer distances. They have a mean free path of about 50 Mega-Parsec. In this surrounding of our galaxy we do not see sources which could produce such high energy protons. If the protons cannot be accelerated to this high energies by objects in our surrounding (up to 50 Mega-Parsec) then one can speculate if these extreme high energy events come from particles which decay in our solar system and originate still from the big bang: Monopoles, Neutralinos, Strings, Wimps, other Dark Matter Particles and Strangelets have been discussed.

The Karlsruhe group is involved in building a large array of 3 000 km^2 in Argentina to study cosmic ray events with energies above 10^{20} eV. This "Auger" array will yield more information about the Greisen–Satsepin cut-off.

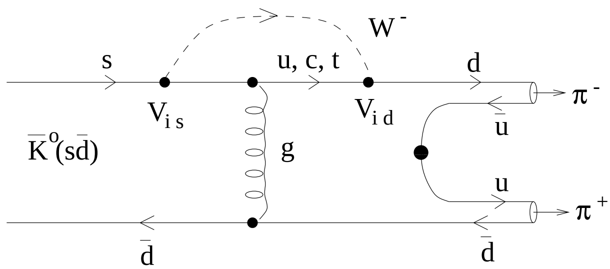

Fig. 5. Diagram contributing to the CP violation in the K^0 decay. The matrix elements V_{is} and V_{id} must be complex in the Cabbibo–Kobayashi–Maskawa matrix to have CP violation.

Zbigniew Włodarczyk speculated in his talk about strangelets. Nuclear matter is for example only stable if we have about the same number of protons and neutrons (symmetric nuclear matter). If one makes nuclear matter symmetric under protons, neutrons and strange particles, one could expect to have even more stable systems. Similar stabilising effects are expected for quark matter by adding strange quarks. These systems of about the same numbers of up, down and strange quarks could perhaps be stable to very large masses. In addition these "strangelets" would have only a small charge.

The existence of these particles is highly controversial. In cosmic ray events one has about two to three measurements, which one would like to attribute to strangelets. An other result is the measurement of the ALEPH detector at LEP, which did run for 10^6 seconds (11.6 days) without the beam. In this time the ALEPH detector measured mainly only events from cosmic rays. In this short time they registered five events with muon numbers between 80 and 160. An event with 100 muons in the ALEPH detector would correspond to a total number of muons of 5 600 in one such event, if one does not have an angular fluctuation, so that almost all muons are concentrated in a small solid angle. Although experts say, that such fluctuations are possible, the result is still very intriguing. It would have been nice to have all LEP detectors at the same time measuring cosmic ray events in coincidence to exclude the possibility of such fluctuations.

3. Fundamental processes in particle physics

In this chapter I want to summarise the talk of Cecilia Jarlskog about the CP-violation in the K^0-system and the lectures about neutrino physics of Danuta Kiełczewska, Adam Para, Amand Faessler, Michael Hass and Hiroyasu Ejiri.

Cecilia Jarlskog spoke about the CP-violation in the decay of the K^0-system. The CP-violation in the wave functions of K_S and K_L has been detected by Cronin and Fitch in 1964 and they got the Nobel prize for that in 1980. This CP-violation is described by a parameter ε while a CP-violation in the decay of which one diagram is given in figure 5 is characterised by a parameter ε'. The measurement of ε' was for a long time very controversial between the team at CERN and the collaboration which measures the same quantity at Fermi Lab. within the error bars they seem now to agree very well:

$$\mathrm{Re}\left(\frac{\varepsilon'}{\varepsilon}\right) = \begin{cases} (15.0 \pm 2.7)\ \times 10^{-4}\ \text{CERN}\,, \\ (20.7 \pm 2.8)\ \times 10^{-4}\ \text{Fermilab}\,. \end{cases} \tag{5}$$

Ms Danuta Kiełczewska reported about the measurement of the atmospheric neutrinos with SuperKamiokande and about the KEK to Kamiokande K2K long baseline neutrino oscillation experiment.

The pions produced by cosmic rays decay in leptons and neutrinos.

$$\begin{aligned} \pi^+(26\ \text{nsec}) &\longrightarrow \mu^+ + \nu_\mu\,, \\ \mu^+(2.2\ \mu\text{sec}) &\longrightarrow e^+ + \bar{\nu}_\mu + \nu_e\,. \end{aligned} \tag{6}$$

The ratio of muon to electron neutrinos for the decay of the π^+ and π^- should be two. But experimentally it is reduced to about 1.3.

SuperKamiokande cannot only distinguish between electron neutrino and muon neutrino events in their Cherenkov detector with a total of about 50 000 tons of pure water, but they can roughly give also the direction from which the neutrino was coming and the neutrino energy, with which the measured light output is increasing.

The data of SuperKamiokande show clearly, that muon neutrinos produced on the opposite side of the earth, this means in the atmosphere above the South Atlantic for energies between 400 MeV and about 1 GeV, are oscillating away, either in a tauon neutrino or into a sterile neutrino. The zenith angle distribution for electron neutrinos is the same as expected without oscillations.

Ms Danuta Kiełczewska showed indications that the muon neutrinos probably oscillate into tauon neutrinos and not into sterile neutrinos. One of these indications is the following:

All three types of neutrinos ν_e, ν_μ and ν_τ have a neutral current interaction with the protons and neutrons from the water. But the recoil of the protons even for extreme high energy neutral current events are too small to produce Cherenkov radiation in the water. But the protons with a recoil of maybe several GeV produce pions (π^+ and π^-), which have a velocity larger than the light velocity in water. So they are producing Cherenkov radiation. The SuperKamiokande collaboration made now cuts on events with several Cherenkov rings (from pions) and on high energy. They also calculated how many such events they should have if the muon neutrino oscillates in tauon neutrinos and if the muon neutrino oscillates in sterile neutrinos, which show no such neutral current interaction. In addition they made a cut only on events coming from below. With an oscillation of muon into tauon neutrinos one expects more such events from below, than when the muon neutrinos are oscillating in sterile neutrinos. The agreement is markedly better between experiment and theory, if one assumes that the muon neutrinos oscillate in tauon neutrinos.

In the long baseline experiment of 250 km from KEK to Super-Kamiokande, one looks for disappearance of muon neutrinos by having a near-side detector at KEK and comparing this rate with the detection by SuperKamiokande. Until the beginning of August 2001 one had measured 44 muon neutrino like events in SuperKamiokande, coming from the direction of KEK and one expects 64.

Adam Para and I (Amand Faessler) gave both two lectures partially with introductory character to neutrino physics.

Amand Faessler reported about the new results from the Sudburry Neutrino Observatory (SNO) in Canada in the Creighton Mine in Ontario, which is 2000 m deep. In addition I reported also about the calculation of neutrino masses in the R-parity violating supersymmetric model.

To be able to measure the charged currents the SNO detector needs weakly bound deuterons, since the solar electron neutrinos of the ^{8}B type have energies only up to 14.6 MeV. The neutrons in ^{16}O are too strongly bound, relative to ^{16}F, so that the corresponding transition is forbidden.

The charge current for electron neutrinos (see figure 6) is determined to be:

$$\begin{aligned}
\Phi^{cc}_{\rm SNO}\ (\nu_e) &= (1.75 \pm 0.23) \times 10^6\ \left[{\rm cm}^{-2}{\rm s}^{-1}\right]\ , \\
\Phi^{\rm ES}_{\rm SK}(\nu_x) &= (2.32 \pm 0.10) \times 10^6\ \left[{\rm cm}^{-2}{\rm s}^{-1}\right]\ , \\
\sigma(\nu_e e^-) &= 6 \cdot \sigma(\nu_\mu e^-)\,. \qquad (7)
\end{aligned}$$

The first line in equation (7) shows the electron neutrino flux measured by SNO (see figure 6 and first line of equation (7)). It is smaller than the neutrino flux derived from the elastic scattering which is sensitive to all

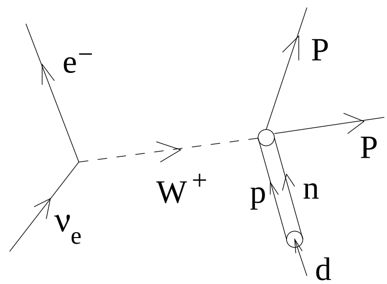

Fig. 6. Charge exchange reaction on the deuteron in heavy water. The electron is detected by Cherenkov radiation.

types of neutrinos. SNO can distinguish the charge current events of figure 6 and the elastic neutrino–electron scattering events by angular distribution. The measurement of SNO for elastic scattering events are too inaccurate to draw conclusions. Thus they used the elastic scattering measurement from SuperKamiokande, published in *Phys. Rev. Lett.* **86**, 5651 (2001) on June 17, 2001. This value of SuperKamiokande is given in the second line of equation (7). This result is obtained assuming there are no oscillations and all the neutrinos coming from the sun are electron neutrinos. Comparing the first and the second line in equation (7) one sees, that the second number is larger and one is forced to assume that some of the electron neutrinos oscillated into muon or tauon neutrinos. Due to the smaller cross-section for the elastic scattering of muon or tauon neutrinos on electrons, the flux of muon and tauon neutrinos must be increased by a factor six of the reduction in the electron neutrino flux. In a diagram of the muon and tauon neutrino flux against the electron neutrino flux one finds an intersection between the two measured quantities in equation (7) and can derive from that the sum of the muon and tauon neutrino flux (8). If one adds the muon and tauon neutrino flux to the electron neutrino flux measured by the charge current interaction by SNO, one obtains a total flux of $(5.44 \pm 0.99) \times 10^6 \left[\mathrm{cm}^{-2}\mathrm{s}^{-1}\right]$ in good agreement with the expected total electron neutrino flux produced by the sun of about $5.1 \times 10^6 \left[\mathrm{cm}^{-2}\mathrm{s}^{-1}\right]$.

$$\begin{aligned}
\Phi^{\mathrm{ES}}_{\mathrm{SK}}(\nu_\mu + \nu_\tau) &= (3.69 \pm 1.13) \times 10^6 \left[\mathrm{cm}^{-2}\mathrm{s}^{-1}\right] , \\
\Phi^{\mathrm{CC}}_{\mathrm{SNO}}(\nu_e) &= (1.75 \pm 0.23) \times 10^6 \left[\mathrm{cm}^{-2}\mathrm{s}^{-1}\right] , \\
\Phi^{\mathrm{total}}(\nu_x) &= (5.44 \pm 0.99) \times 10^6 \left[\mathrm{cm}^{-2}\mathrm{s}^{-1}\right] , \\
\Phi^{\mathrm{theory}}(\nu_e) &\approx 5.1 \times 10^6 \left[\mathrm{cm}^{-2}\mathrm{s}^{-1}\right] . \qquad (8)
\end{aligned}$$

I also reported calculations within the R-parity violating supersymmetric model for the neutrino masses, fitting the free parameters to the solar

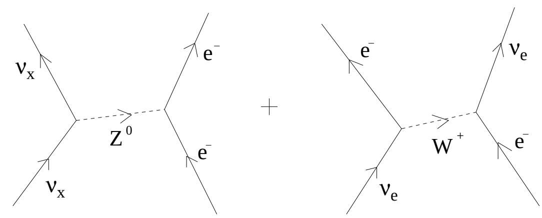

Fig. 7. Elastic scattering of neutrinos on electrons. The neutral current interaction is sensitive to all neutrinos ν_e, ν_μ and ν_τ (not to sterile neutrinos), while the charged current interaction is only sensitive to electron neutrinos. The events of Fig. 6 and Fig. 7 can be distinguished by angular distribution.

and atmospheric neutrino oscillation data. Supersymmetry produces only Majorana neutrinos. The calculation is performed under the assumption that CP symmetry is not violated, but this leaves still open CP phases with the values $+1$ or -1. Since one has two such phases for Majorana neutrinos, one has four undertermined possibilities, which produce the range of uncertainties, shown in equation (9).

$$\begin{aligned} m_1(\sim \nu_e) &\approx 0.001 \to 0.02 \text{ eV}\,, \\ m_2(\sim \nu_\mu) &\approx 0.01 \quad \to 0.04 \text{ eV}\,, \\ m_3(\sim \nu_\tau) &\approx 0.03 \quad \to 1.00 \text{ eV}\,. \end{aligned} \tag{9}$$

Adam Para gave a nice series of lectures introducing into neutrino oscillations with three flavours. He also spoke about the long baseline neutrino oscillation experiment MINOS from Fermi Lab to the Sudan mine with an oscillation distance of 730 km. This experiment should be taking data in the year 2003. There are similar plans for CERN to Gran Sasso (750 km). These are the projects OPERA and ICARUS which should be ready for data taking in 2005.

Hitoyasu Ejiri spoke about the double beta decay, which is the *experimentum crucis* to distinguish Dirac from Majorana neutrinos. The double beta decay is only possible, if the neutrino is a Majorana particle and by that (apart from a phase) identical with its antiparticle. The distinction between Dirac and Majorana neutrinos makes only sense in models beyond the standard model. In the standard model with exactly zero neutrino masses the prediction of both types of neutrinos is completely identical for Dirac and Majorana neutrinos, because the same selection rules due to neutrinos and antineutrinos is taken over by the helicity, which is a good quantum number for massless neutrinos.

The transition amplitude for the neutrinoless double beta decay is proportional to an expectation value of the electron neutrino mass, to the righthandedness of the weak interaction, to the mass ratio of the light vector boson responsible for the left-handed weak interaction to a heavy vector boson, which is in left-right-symmetric models responsible for the right-handed weak interaction, and to the square of a coupling constants from supersymmetry.

$$T(0\nu\beta\beta) \; = \; M_m\langle m_\nu\rangle + M_{\rm RL}\langle\tan\vartheta\rangle + M_{\rm RR}\left\langle\left(\frac{M_{\rm WL}}{M_{\rm WL}}\right)^2\right\rangle + M_{\rm SUSY}\lambda_{111}^2\,. \tag{10}$$

If one has now an upper limit for the neutrinoless double beta decay transition probability and one assumes that one mechanism is the leading one, one can get upper limits for the different parameters: the averaged electron neutrino mass $\langle m_\nu\rangle$, the admixture of the heavy vector boson responsible for the right-handed weak interaction to the light vector boson $\langle\tan\theta\rangle$, for the ratio squared of the mass of the vector bosons responsible for the left-handed weak interaction divided over the mass of the vector boson responsible for the right-handed weak interaction and for the square of the coupling constant λ_{111} of the R-parity violating supersymmetric model. The averaged electron neutrino mass $\langle m_{\nu e}\rangle \leq 0.6$ eV can be reduced in further double beta decay experiments like MOON. Hiroyasu Ejiri convinced us that he is able to reduce this limit down to 0.03 eV.

4. New plans of the GSI and first results from RHIC

Volker Metag and Peter Senger presented us the new plans of the GSI to build a high intensity proton and heavy ion synchrotron with 200 Teslameter, with a possible extention to 250 Tesla-meters. This would allow to accelerate protons to 60 (or 75) GeV and uranium to 23 (or 29) AGEV.

These high intensity (and partially also high energy) beams would allow four types of physics:

(i) The high energy uranium could for example be fragmented and one obtains intense beams of short-lived nuclei starting with 10^{12} uranium nuclei per second of 1 GeV per nucleon.

(ii) Another possibility would be to use the high energy heavy ion beams of for example ^{238}U at 22 GeV per nucleon to study nuclear matter at the highest baryon densities. This would allow to explore the nuclear matter phase diagram and perhaps even go to the quark–gluon phase transition, but opposite to the quark–gluon phase transition at RHIC or LHC physics this matter would have a high baryon density.

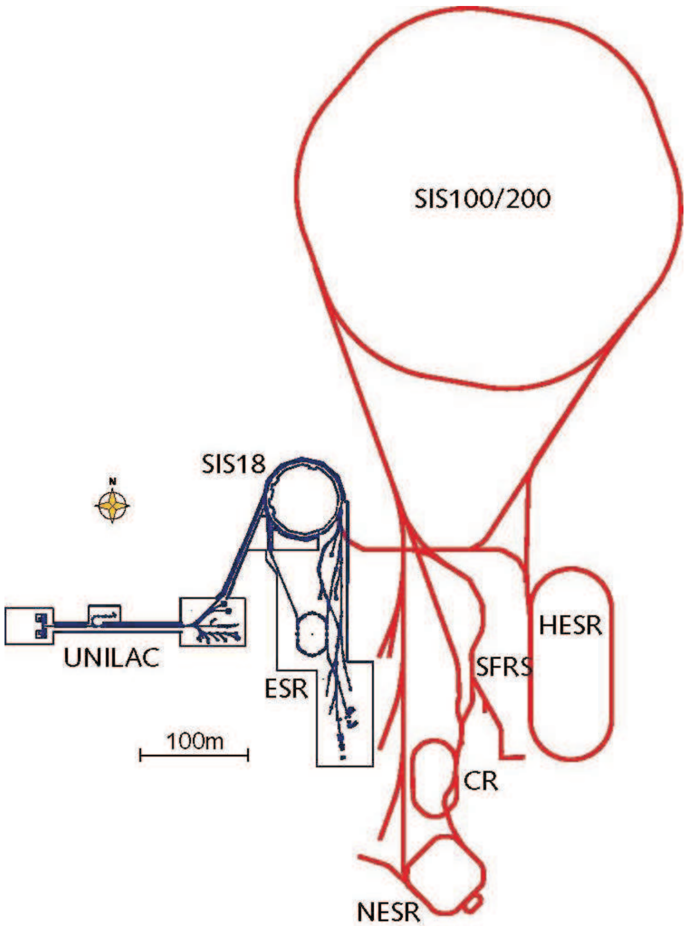

Fig. 8. Outline of the future plans of the GSI with a 100 Teslameter (SIS 100) and a 200 Teslameter (SIS 200 perhaps extended to SIS 350) ring (see text).

(iii) The intense proton beams with about 30 GeV would allow to produce cooled antiproton beams of the order of 12 GeV which one could re-accelerate again in the 200 Tesla-meter ring and send it into a high energy storage ring.

(iv) The last possibility would be to produce a usual plasma with heavy ion pulses of about 500 MeV per nucleon with a very high power density of the order of 20 kJ. This would allow to study plasma physics with matter at the extremes of pressure and temperature.

The outline of the new GSI project can be found in figure 8.

Volker Metag described especially the antiproton project. An intense proton beam is accelerated up to 30 GeV on an antiproton target. The antiprotons are then cooled in two rings and then re-injected into SIS 200 and re-accelerated again and then stored in a high-energy storage ring (HESR). These antiprotons allow to do J/Ψ spectroscopy and to explore the confinement region of QCD of a few GeV. One can also search for glueballs and for hybrids. The energy allows also to study hidden and open charm mesons in nuclei and to investigate hypernuclei.

Prof. Aandrzej Budzanowski form Cracow presented the first results of RHIC from the PHOBOS collaboration.

RHIC can collide 100 GeVA gold on 100 GeVA gold with a center of mass energy of 200 GeVA. The experiment about which Prof. Andrzej Budzanowski was reporting, was done for Au on Au with a center of mass energy of 130 GeVA. By fitting ratios of the different produced particles (pions, baryons and antibaryons), one obtains the result shown in Table I.

TABLE I

Baryon Fermi-energy (Baryon potential) and temperatures for the reactions Pb + Pb with $E_{\rm CM} = 17.6$ GeV A at CERN and Au + Au with $E_{\rm CM} = 130$ GeV A at RHIC derived from the ratios of the particles produced.

	SPS (CERN)	RHIC
μ Baryon [MeV]	270	41
Temperature [MeV]	170	170

Going from the 17.6 GeV A at SPS (CERN) to the 170 GeV A at RHIC, one reduces the baryon potential μ_B from 270 to 41 MeV. This means the central region has a much lower baryon density at RHIC than at CERN, but a very high energy density. On the other side the temperature of 170 MeV is not changing from SPS to RHIC. This suggests that in both cases one transversed the nuclear matter to the quark–gluon plasma phase transition and the observed particles are a result of the condensation from the quark–gluon plasma into the thermal equilibrium at a temperature of 170 MeV for the different baryon densities.

Since I am the last non-polish speaker, I have the privilege to thank the organizers for the nice atmosphere and the interesting surrounding at this school. Our thanks go to Ziemowid Sujkowski, who is the chairman of the organizing committee and carried most of the responsibility. But the good atmosphere is also due to Danka Chmielewska and to Kasia Delegacz. The sailing was as in all previous schools excellently organized by Jan Kownacki. We could rely on the organization of our transports by Anna Stolarz. The proceedings are prepared by Tomasz Matulewicz, who has to take care that we all send our manuscripts to him on time. There where also many others involved in the organization, which I include in my thanks also.

We are all looking forward to come again to one of the Mazurian Lakes Schools in the future.