FISSION OF LEAD PROJECTILES IN Pb-NUCLEUS COLLISIONS AT THE SPS

Presented by E. Vercellin for the NA50 collaboration

M.C. Abreu[a*], B. Alessandro[l], C. Alexa[d], R. Arnaldi[l], J. Astruc[i], M. Atayan[n], C. Baglin[b], A. Baldit[c], M. Bedjidian[m], F. Bellaiche[m], S. Beolè[l], V. Boldea[d], P. Bordalo[g†], A. Bussière[b], L. Capelli[m], V. Caponi[b], L. Casagrande[g], J. Castor[c], T. Chambon[c], B. Chaurand[j], I. Chevrot[c], B. Cheynis[m], E. Chiavassa[l], C. Cicalò[e], M.P. Comets[i], N. Constans[j], S. Constantinescu[d], P. Cortese[l] J. Cruz[g], A. De Falco[e], N. De Marco[l], G. Dellacasa[a] , A. Devaux[c], S. Dita[d], O. Drapier[f,m], L. Ducroux[m], B. Espagnon[c], J. Fargeix[c], A. Ferretti[l] S.N. Filippov[h], F. Fleuret[j], P. Force[c], M. Gallio[l], Y.K. Gavrilov[h], C. Gerschel[i], P. Giubellino[l], M.B. Golubeva[h], M. Gonin[j], A.A. Grigorian[n], J.Y. Grossiord[m], F.F. Guber[h], A. Guichard[m], H. Gulkanyan[n], R. Hakobyan[n], R. Haroutunian[m], M. Idzik[l‡], D. Jouan[i], T.L. Karavitcheva[h], L. Kluberg[j], A.B. Kurepin[h], Y. Le Bornec[i], C. Lourenço[f], P. Macciotta[e], M. Mac Cormick[i], A. Marzari-Chiesa[l], M. Masera[l], A. Masoni[e], S. Mehrabyan[n], M. Monteno[l], S. Mourgues[c], A. Musso[l], F. Ohlsson-Malek[m§], C. Oppedisano[l] P. Petiau[j], A. Piccotti[l], J.R. Pizzi[m], W.L. Prado da Silva[l¶], G. Puddu[e], C. Quintans[g], C. Racca[k], L. Ramello[a], S. Ramos[g†], P. Rato-Mendes[l], L. Riccati[l], A. Romana[j], I. Ropotar[f], P. Saturnini[c], E. Scalas[a] E. Scomparin[f‖], S. Serci[e], R. Shahoyan[g**], S. Silva[g], M. Sitta[l], C. Soave[l], P. Sonderegger[f†], X. Tarrago[i], N.S. Topilskaya[h], G.L. Usai[e], E. Vercellin[l], L. Villatte[i], N. Willis[i].

[a] Universitá del Piemonte Orientale, Alessandria and INFN-Torino, Italy
[b] LAPP, CNRS-IN2P3, Annecy-le-Vieux, France.
[c] LPC, Univ. Blaise Pascal and CNRS-IN2P3, Aubière, France.
[d] IFA, Bucharest, Romania.
[e] Università di Cagliari/INFN, Cagliari, Italy.
[f] CERN, Geneva, Switzerland.
[g] LIP, Lisbon, Portugal.
[h] INR, Moscow, Russia.
[i] IPN, Univ. de Paris-Sud and CNRS-IN2P3, Orsay, France.
[j] LPNHE, Ecole Polytechnique and CNRS-IN2P3, Palaiseau, France.
[k] IRS, Univ. Louis Pasteur and CNRS-IN2P3, Strasbourg, France.
[l] Università di Torino/INFN, Torino, Italy.
[m] IPN, Univ. Claude Bernard Lyon-I and CNRS-IN2P3, Villeurbanne, France.
[n] YerPhI, Yerevan, Armenia.

[*] Also at UCEH, Universidade de Algarve, Faro, Portugal
[†] also at IST, Universidade Técnica de Lisboa, Lisbon, Portugal
[‡] now at Faculty of Physics and Nuclear Techniques, University of Mining and Metallurgy, Cracow, Poland
[§] now at ISN, Univ. Joseph Fourier and CNRS-IN2P3, Grenoble, France
[¶] now at UERJ, Rio de Janeiro, Brazil
[‖] on leave of absence from Università di Torino/INFN, Torino,Italy
[**] on leave of absence of YerPhI, Yerevan, Armenia

1. Experimental method and results

Fission of Pb projectiles is at present investigated by the NA50 experiment at CERN SPS. After the initial studies (1996 data taking) that led to the observation of fission in Pb-Pb interactions at 158 AGeV [1], data have been taken on different target nuclei in 1998, both at 40 and 158 AGeV. The analysis of the 40 AGeV data is at present in progress, while the preliminary results at 158 AGeV are presented here.

The experimental apparatus (basically the same in 1996 and 1998) is described in detail in ref. [1]. Here we simply recall that a quartz Cherenkov detector (the so called Fragment Detector, FD) has been added to the standard NA50 layout for fission measurements. This detector is placed on the beam trajectory downstream from the target, just in front of the Zero-degree calorimeter (ZDC). The FD consists of a SiO_2 blade shaped as a truncated pyramid (about 20×20 mm^2 in area and 2 mm thick). The Cherenkov light is totally reflected on the pyramid bases and collected to a photomultiplier by quartz optic fibers. The acceptance of the fragment detector ($\eta \geq 6.3$, defined by a collimator) corresponds to the projectile fragmentation region. Since the yield of Cherenkov light is proportional to the squared charge of the particle, the quantity measured by the fragment detector is $\sum(Z_i)^2$, where Z_i is the charge of the i-th fragment emitted in the projectile decay. In case of symmetric (or quasi-symmetric) binary fission, a concentration of events is expected at $\sum(Z_i)^2{=}2(Z_{Pb}/2)^2{=}(Z_{Pb})^2/2$.

While in 1996 fission studies were carried out in parallel to standard NA50 data taking, in 1998 fission was investigated in a short dedicated run. For each target (C, Al, Ag, Cu and Pb, thickness ranging from 1 to 4 mm), data were taken with two different triggers. The first one (ZDC trigger) is obtianed by requiring a minimum energy deposition in the ZDC and allows to collect an "unbiased" sample of events, ranging from central collisions to uninteracting Pb-ions. The second one (ZDC·FD) is built-up by asking (together with the ZDC trigger) a light output of the FD smaller than the one of uninteracting beam. This allows to reject uninteracting Pb-ions and to improve the statistics for fission events. For each target, the number of fission events per incident Pb-ion (and hence the fission cross section σ^f) is deduced from the light-output (ADC) distributions of the FD obtained with the two triggers. The distributions recorded with the ZDC·FD trigger for the carbon and lead targets are respectively shown in fig. 1 and 2. In both cases the fission peak is visible at ch. 400.

The fission cross sections σ^f are plotted in fig. 3 as a function of the charge of the target nucleus Z_t. The cross sections are corrected for the probability of reinteraction of the fission fragments in the target as well as for projectile absorption prior to fission. It is worth to note that the Pb-Pb fission cross section measured in this experiment is consistent with the one (about 340 mb) recently reported by the emulsion experiment EMU13 [2].

2. Fission mechanism

In heavy-ion collisions, fission can be induced both by nuclear and electromagnetic interaction. When two nuclei collide at impact parameters b larger than the cutoff impact parameter b_{min} (which is close to the sum of the nuclear radii [3]) the interaction is purely electromagnetic. Each nucleus experiences the strong Lorentz-contracted electromagnetic

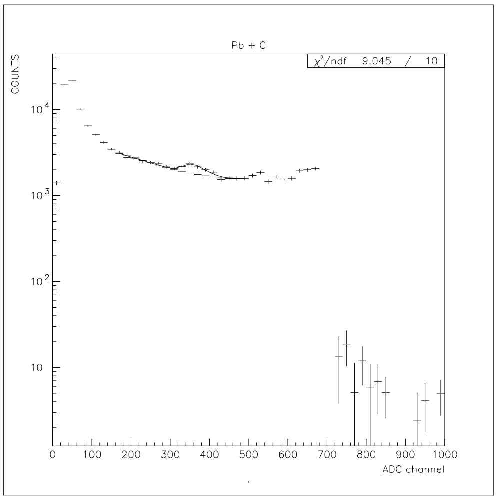

Figure 1. Light output (ADC) distribution of the fragment detector for carbon target.

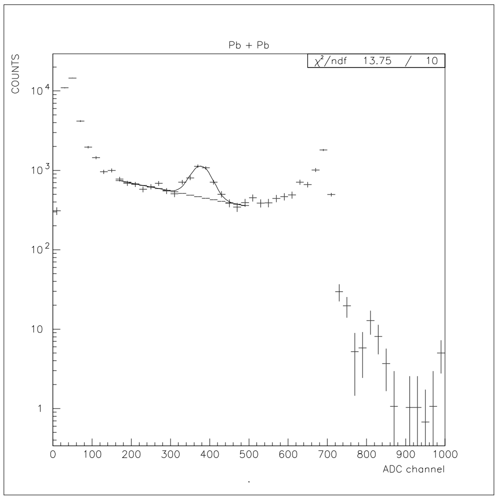

Figure 2. Light output (ADC) distribution of the fragment detector for lead target.

field of the other nucleus which, at ultrarelativistic energies, can be expressed in terms of the Weizsacker-Williams (WW) equivalent photon spectrum $n(\omega)$, where ω is the energy of the virtual photon [4]. The cross section for e.m. fission of the projectile is given, at the first order, by:

$$\sigma^f_{em} = \int n(\omega)\sigma^{\gamma f}(\omega)d\omega \tag{1}$$

where $\sigma^{\gamma f}(\omega)$ is the photofission cross section of the projectile and $n(\omega)$ is the number of virtual photon radiated by the target nucleus. Since this last number is approximately proportional to Z_t^2, σ^f_{em} is expected to scale as Z_t^2

To disentangle the contributions arising from the nuclear and electromagnetic fission mechanisms, a strategy similar to the one proposed in studies of ^{238}U fission at lower energies ([5],[6]) is adopted. The measured fission cross section σ^f is assumed to be the sum of the nuclear and e.m. components (σ^f_N and σ^f_{em}) and a geometrical model is used to evaluate the behaviour of σ^f_N as a function of the target mass A_t. The model is based on the idea that only peripheral collisions, with $b \simeq b_{min}$, contribute to the nuclear fission cross section. Since the cutoff impact parameter is close to the the sum of the radii of the target and projectile nuclei, σ^f_N is assumed to scale as $(A_t^{1/3} + A_p^{1/3})$, where A_p is the projectile mass number. Under these assumptions, σ^f is expected to behave as

$$\sigma^f = \sigma^f_N + \sigma^f_{em} = c_1 \cdot Z_t^2 + c_2 \cdot (A_t^{1/3} + A_p^{1/3}) \tag{2}$$

The free parameters c_1 and c_2, and hence the nuclear and e.m. contributions to the fission cross section, have been estimated by fitting the data points of fig. 3. The result of the fit is also shown in this figure.

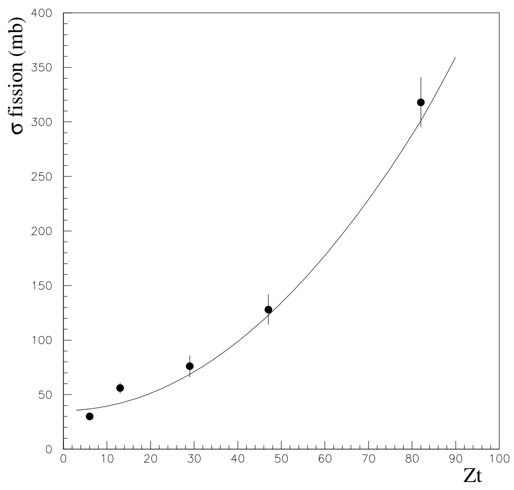

Figure 3. Fission cross sections for Pb-projectiles at 158 AGeV plotted as a function of the target charge number Z_t. The solid line is a fit to the data according to eq. (2).

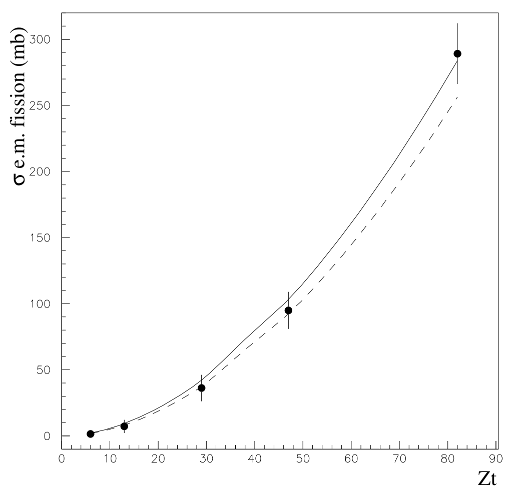

Figure 4. Cross sections for electromagnetic fission of Pb projectiles at 158 AGeV. The two curves are the predictions of the WW calculation (see text).

The cross sections for e.m. fission obtained with this procedure are plotted in fig. 4 as a function of Z_t. In the same figure are also shown the first-order WW cross section computed by inserting in eq.(1) the photofission cross section data for ^{208}Pb from ref. [7]. Since these data are limited to photon energies below 1 GeV, two curves corresponding to different extrapolations to higher energies are shown.

As it can be seen in fig. 4, no spectacular deviation from the WW predictions is shown by the preliminary data. It is worth to note explicitely that complementary information is provided by e.m.fission and e.m. dissociation in the neutron channel, since the two reactions are sensitive to different energy regions of the virtual photon spectrum $n(\omega)$. This is due to the fact that the photofission cross section $\sigma^{\gamma f}(\omega)$ reaches its maximumum for $\omega \simeq 350$ MeV, i.e. for photon energies much higher than those needed to excite the Giant Dipole Resonance.

REFERENCES

1. M.C. Abreu et al., Phys. Rev. C . 59, 876 (1998)
2. M.L. Cherry et al., Acta Phys. Polonica B 29 (1998)
3. C.J. Benesh et al., Phys. Rev. C . 40, 1198 (1989)
4. C.F. Weizsacker, Z. Phys. 88, 612 (1934); E.J. Williams, Phys. Rev. 45, 729 (1934)
5. Th. Rubehn et al., Z. Phys. A 353, 197 (1995)
6. M. Justice et al., Phys. Rev. C . 49, R5 (1994)
7. L.G.Moretto et al., Phys. Rev. 179, 1176 (1969)