Proposal for a Light Universal Detector for the Study of Correlations between Photons and Charged Particles

Angelis, Aris L. S.; Fokin, S; Beckmann, P.; Löhner, Herbert

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Addendum 2 to Proposal P252

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University of Geneva, Switzerland

A. Angelis, P. Dönni, E. Durieux, M. Iżycki, M. Martin, L. Rosselet, N. Solomey

GSI-Darmstadt, FRG

R. Bock, H. H. Gutbrod, B. W. Kolb, I. Lund, H. R. Schmidt

University of Jammu, India

N. K. Rao

Kurchatov Inst. Moscow, USSR

S. Fokin, M. Ippolitov, K. Karadjev, A. Lebedev, V. Manko, A. Vinogradov

KVI-Groningen, NL

P. Beckmann, H. Löhner

University of Lund, Sweden

G. Claesson, A. Eklund, S. Garpman, H. Å. Gustafsson, J. Idh, A. Oskarsson, I. Otterlund, K. Söderström, E. Stenlund

University of Münster, FRG

F. Berger, D. Bock, G. Clewing, L. Dragon, R. Glasow, M. Hartig, G. Hölker, K.-H. Kampert, T. Peitzmann, M. Purschke, B. Roters, R. Santo, K. Steffens, P. Steinhäuser, D. Stüken, A. Twyhues

Oak Ridge National Lab, USA

T. C. Awes, R. L. Ferguson, F. E. Obenshain, F. Plasil, S. Saini, M. L. Tincknell, G. R. Young

Punjab University, Chandigarh, India

V. S. Bhatia, I. S. Mittra

University of Jaipur, Rajasthan, India

K. B. Bhalla, S. Lokanathan

University of Tennessee, Knoxville, USA

A. Franz, S. P. Sorensen

VECC Calcutta, India

S. Bhattacharya, C. Chattopadhyaya, S. Murhtey, B. Sinha, Y. P. Viyogi

Spokesman: H. H. Gutbrod

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This Addendum No.2 is written in view of the future plans and involvements of our collaboration in the coming CERN heavy ion programs, be it the 1992 Sulfur run, Pb beams in the SPS or later Pb + Pb collisions at the LHC.

1 Prologue

On September 11,1990, the SPSC rejected our plans for the construction and implementation of a BGO detector for the search of direct photons as a possible signal for the production of the quark gluon plasma. The P252 collaboration has removed the BGO from the proposed setup, as pointed out in the Addendum No. 1.

In communications with Profs. Donnachie and Darriulat we were informed that the main reason for this negative decision of the SPSC on September 11, 1990, was that its members were not convinced that direct photon detection can be achieved in heavy-ion reactions at the necessary level of accuracy. Furthermore, the committee considered the price of the proposed detector concept as too high for the expected yield in physics.

We do not share this opinion and would like to make the following comments:

(i) New calculations show that direct photon measurements are more promising than dilepton measurements, especially at RHIC and LHC.

(ii) The achieved accuracy of 15% for the γ_{direct}/π^0 ratio in impact parameter selected ^{16}O reactions, the bad performance in the 1987 sulfur run due to a too high particle density in the detector, and the successful run in 1990 with the proper geometry, give us confidence to continue with the search for direct photons, be it at the lead beam at the SPS, at RHIC, or at the LHC. (At RHIC at least 3 letters of intent have been submitted for the direct photon search employing the same or similar technologies.)

(iii) Our collaborators from ORNL have obtained \$ 1 000 000 solely for BGO.

(iv) The USSR have developed a BGO production of excellent quality and will deliver until end of 1992 one thousand longitudinally segmented BGO modules to the collaboration.

2 To (i): Physics Interest in Direct Photons

The cleanest signals for the expected formation of a QGP known so far are direct photons and lepton pairs since they are not affected by the hadronic environment but interact only via the electro-weak force. Calculations which have been performed for these processes predict in the relevant $p_\perp$ region of $1 - 3$ GeV/c a production rate of thermal photons between $\gamma/\pi^0 \simeq 5\%$ and nearly 100% depending on the bombarding energy and the size of the nuclear system. The most recent calculations (presented by P.V. Ruuskanen on the LHC workshop in Aachen 1990) show that in this region thermal dileptons are unlikely to be detected due to the large Drell-Yan cross sections. In case of direct photons the Drell-Yan contributions are significantly smaller and the hadronic decays can be reconstructed with proper detection techniques, thus, a detection of the signal is within the range of achievable accuracy. In future RHIC and LHC reactions the γ_{direct}/π^0 ratio is expected to rise even to 60 - 100%, clearly incentive enough to get prepared for this signal.

3 To (ii): Achieved Sensitivity in γ/π^0

A very detailed analysis of the ^{16}O data from the first heavy-ion run of 1986 has now been completed and its results are written up in a draft for publication. Within the present errors there is no evidence for direct photons in 200 AGeV p,^{16}O + nucleus reactions (see figure 1 and 2 which are taken from this draft and were handed to our referee). Conservative evaluation of the errors (listed in table 1) leads to a value of $\gamma/\pi^0 \leq 15\%$ (90% CL) in the $p_\perp$ region from $0.5 - 2.5$ GeV/c.

While some of the systematic errors can only slightly be improved, others can appreciably be reduced by additional coverage, statistics, and systematic error studies. In the ^{32}S run 1990 we employed in addition to the SAPHIR detector two additional lead-glass towers increasing the detector area by abouta factor of 3 (see CERN/SPSC 90-14; SPSC/P252). Based on the experience with the experimental O-data and their processing a rigorous estimate of the achievable error of γ/π^0 in the S run has been made and presented by the spokesman of the collaboration at the SPSC meeting on July 10/11, 1990: expecting 20 Million events and leaving all other conditions unchanged we arrived at an estimate of the error of 5 – 6%. Although the detectors all worked properly in the run we got only 12 Mio. events due to the bad S beam performance particularly during the first weeks. The expected error will therefore be only as low as about 7%. Data processing is underway, and we expect preliminary γ/π^0 data from the S run by April '91.

4 The BGO Upgrade

As already sketched in documents CERN/SPSC 89-73; SPSC/I 173, in CERN/SPSC 90-14; SPSC P252 and its addendum sent to our referee, the much increased multiplicity in a Pb beam scenario requires application of high resolution detectors with high shower separation and hadron suppression particularly for the lower $p_\perp$ region. Detailed studies have shown that BGO is best suited for this purpose.[1] Since many questions connected with nuclear beams and high multiplicities can only be studied in a real heavy-ion environment we proposed to build a two arm prototype BGO detector for the 1991/92 run with minimal acceptance to reconstruct π^0 in the $p_\perp$ region from 0.15 – 4 GeV/c (see fig. 3 and 4). Reconstruction of neutral pions is mandatory, since all disturbances of the photon identification that enter sensitively in the γ/π^0 signal are reflected in the π^0 reconstruction performance.

With the proposed two-arm spectrometer we thus will gain working knowledge of the first very high resolution spectrometer operated in the hostile environment of ultra-relativistic heavy-ion reactions and we will in addition produce interesting new data in the 1992 S-run, particularly in the low $p_\perp$ region. Since submission of the proposal P252 the question of low $p_\perp$ pion spectra has attracted increased attention since new calculations[2] show that the rise of the cross section cannot be understood by any type of secondary or rescattering within the nucleus but has new and yet unknown reasons. Since a dominant part of low $p_\perp$ pions originates from resonance decays a detailed comparison of charged and neutral pions is highly desirable.

[1] In the document CERN/SPSC 89-36; M444 we have discussed the advantages of BGO over other high resolution calorimeter materials. Commenting to the very recent discussions in the SPSC about CsI as a competitive material we would like to add to the arguments that the costs for CsI are about the same or even more expensive as for BGO when counted as $D^2 \times X_0$ (D = cross section of a rectangular module containing 80% of the em-shower energy); for CsI one finds: $4.4^2 \times 1.86 = 36.0\text{cc} \simeq \$\ 90$ (assuming \$ 2.5/cc), and for BGO: $2.5^2 \times 1.12 = 7.0\text{cc} \simeq \$\ 70$ (assuming \$ 10.0/cc).

[2] H.W. Barz, G. Bertsch, D. Kusnezov, and H. Schulz, Michigan State University Preprint, 1990.

4.1 Prototype Studies and Developments

Prototype BGO modules have been ordered and were tested in an electron beam from 1 to 40 GeV/c in order to measure the energy- and position resolution with the new developed electronic readout chain designed at ORNL. It consists of a low noise preamplifier fed into a 6-gain stage shaping amplifier, corresponding to a 20 bit ADC or better. Production of a hybrid version of the preamp has just started at ORNL. All those tests confirmed the expected performance of an energy resolution of 1% at 10 GeV/c and a position resolution of 1 mm.

In order to improve furthermore significantly on the electron/hadron resolving power as well as on the two shower separation additional tests are just being prepared with longitudinally segmented modules (see CERN/SPSC 90-14; SPSC P252).

To (iii) and (iv): Procurement of BGO

The Oak Ridge part of our collaboration has received appreciable funding by the US-DOE, which is explicitly assigned for BGO to be implemented in our proposed setup.

The Lund University team has money earmarked for the BGO to be later used in the lead beam experiment.

The Kurchatov Institute, Moscow, as member of our collaboration, is in addition capable of delivering large amounts of BGO to be implemented in future setups, as indicated above.

All these contributions are neither convertible in different parts of experimental equipment nor in an equivalent amount of financial funding ~~serving~~ our plans at the SPS at CERN.

Summarizing, we kindly request a reconsideration of the BGO part of proposal P252 regarding all this additional information that might have not been sufficiently known by the SPSC members. The recently discussed very tough problems in disentangling thermal dileptons from Drell-Yan pairs leave the search for thermal direct photons as the most promising signal for the thermalization. Based on our achieved results and the experience gained in oxygen and sulfur runs we are willing to tackle this admittedly difficult task employing the appropriate methods and techniques.

We have demonstrated that direct photon detection can be achieved in O and S beams with an accuracy of 7 – 15%. Simulations based on this experience have demonstrated that similar accuracy can be obtained also in Pb-beam scenarios. However, in the lower $p_\perp$ region partial coverage with high resolution materials such as BGO would be required.

In order to direct our future efforts on this topic properly and in view of presenting a lead-beam proposal, due end of March '91, we would be very much indebted if the SPSC could substantiate its critiques and doubts to the outlined physics and proposed experimental realization in a clear statement.

Table 1: Systematic and statistical errors of the γ/π^0 calculation.

statistical error	$\pm 6\%$
geometrical π^0 acceptance	$\pm 3\%$
nonlinearity	$\pm 3\%$
photon reconstruction efficiency	$\pm(4-8)\%$
veto efficiency	$+0.1\%$
m_T scaling	$\pm 1\%$
η/π^0 induced error on the background calculation	$\pm 4\%$
quadratic sum	$\pm(9-12)\%$

Fig. 1: Ratio of inclusive photon cross section to π^0 cross section as a function of transverse momentum for 200 AGeV p+C, p+Au, O+C, and 60 AGeV O+Au events under minimum-bias trigger conditions. The squares indicate the data, and the shaded histograms are the Monte Carlo results representing hadronic decays (results to be submitted for publication).

Fig. 2: Ratio of inclusive photon cross section to π^0 cross section as a function of transverse momentum for central and peripheral 200 AGeV O + Au reactions. The squares indicate the data, and the shaded histograms are the Monte Carlo results representing hadronic decays (results to be submitted for publication).

Fig. 3: Sketch of the layout of the already existing 3788 lead-glass modules plus a two-arm 500 + 500 module BGO detector.

Fig. 4: Simulated invariant mass spectra for a two-arm BGO photon spectrometer, each comprising 500 modules for 100k central S + Au reactions. Only photon pairs between the two arms are considered. Energy- and position resolution as well as photon reconstruction efficiency are taken into account in the simulation.

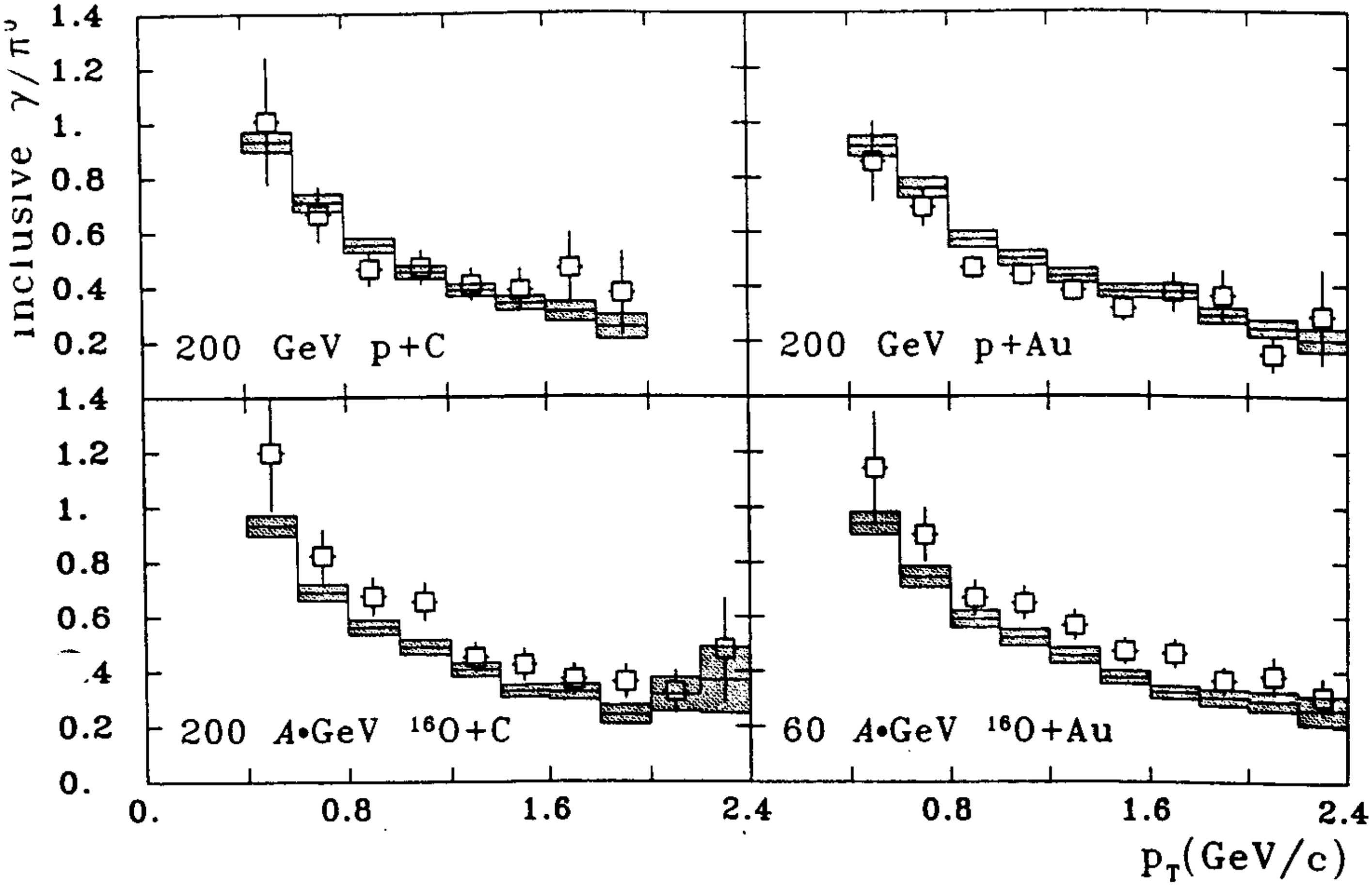

inclusive γ/π^0
200 GeV p+C
200 GeV p+Au
200 A•GeV ^{16}O+C
60 A•GeV ^{16}O+Au
p_T(GeV/c)

Fig. 1

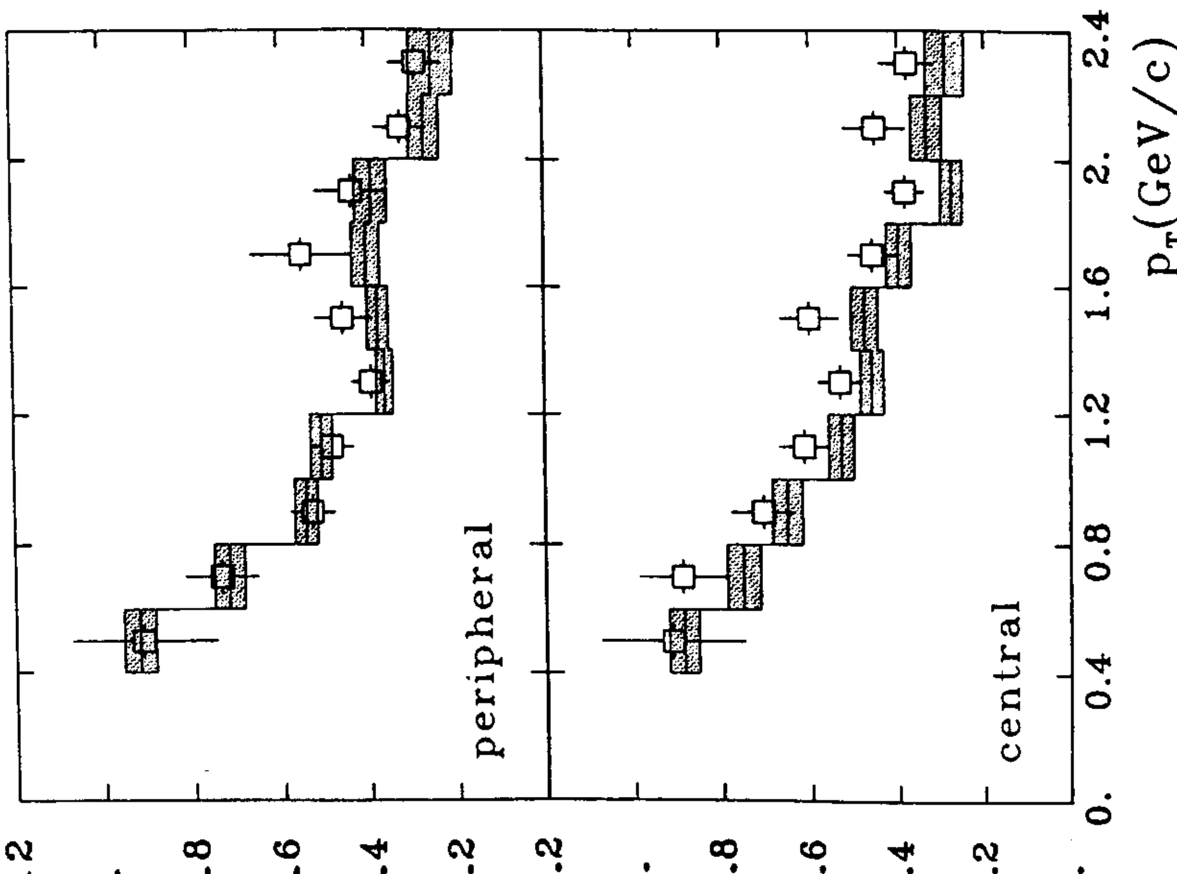
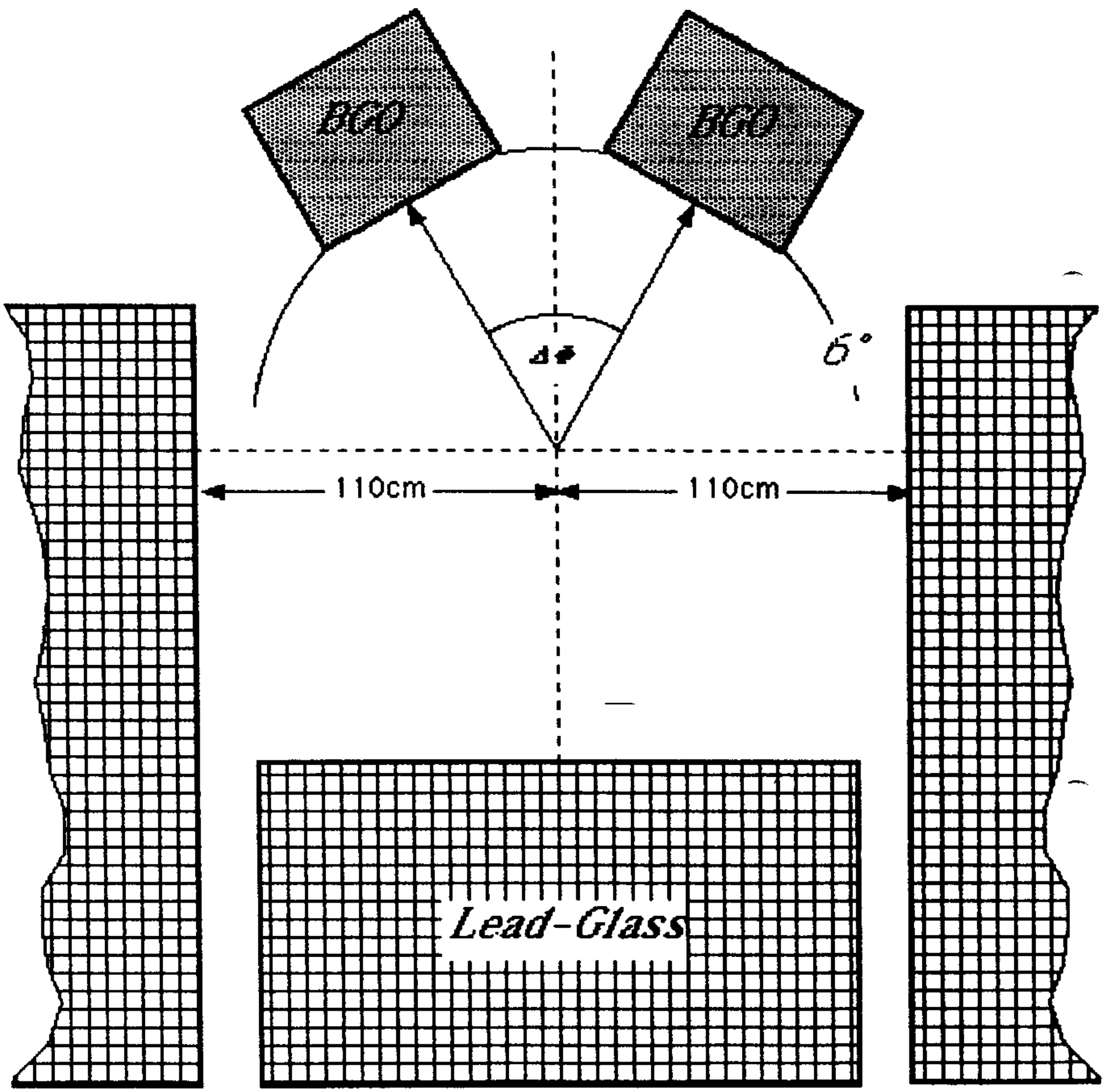
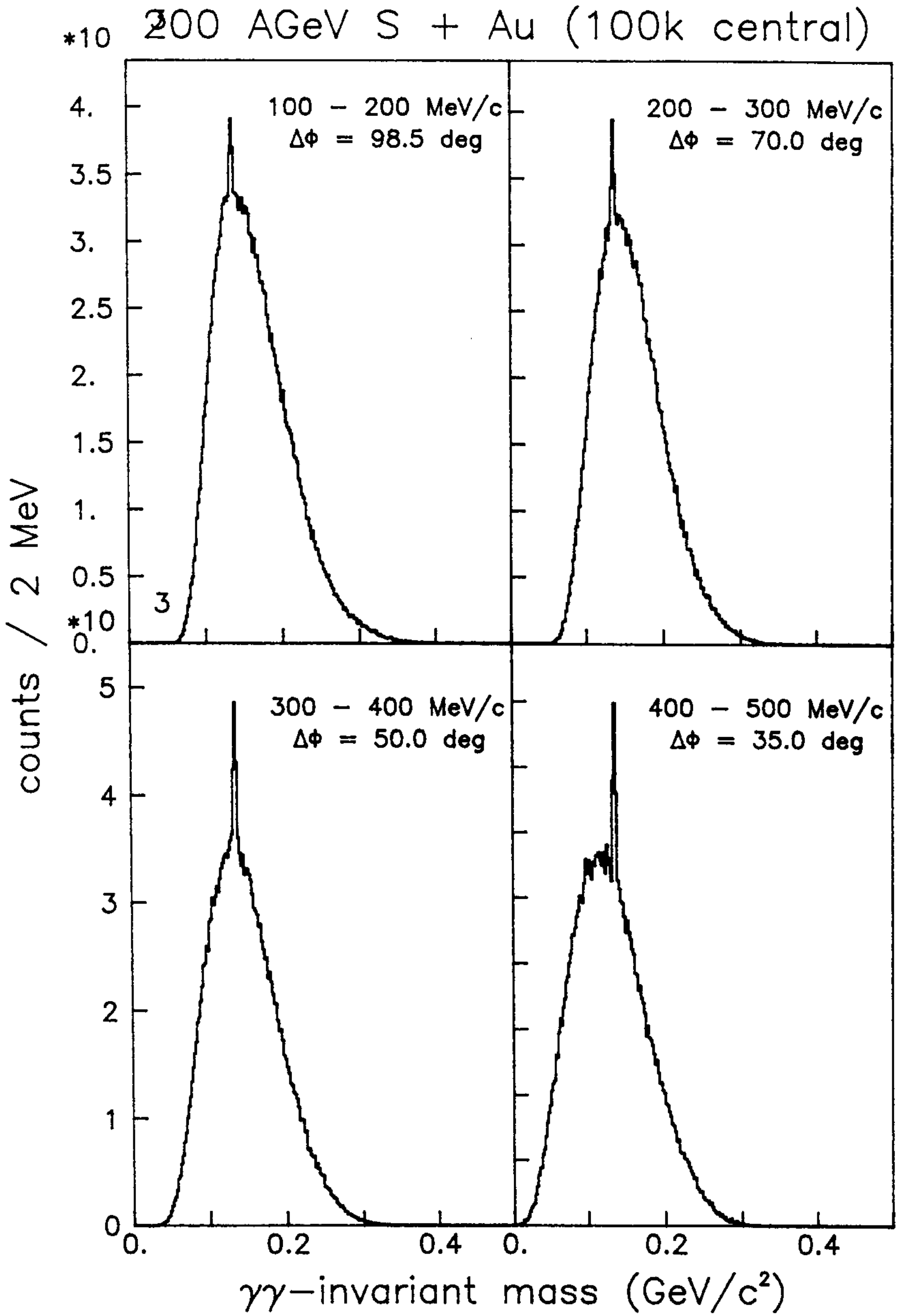

peripheral
central
p_T(GeV/c)

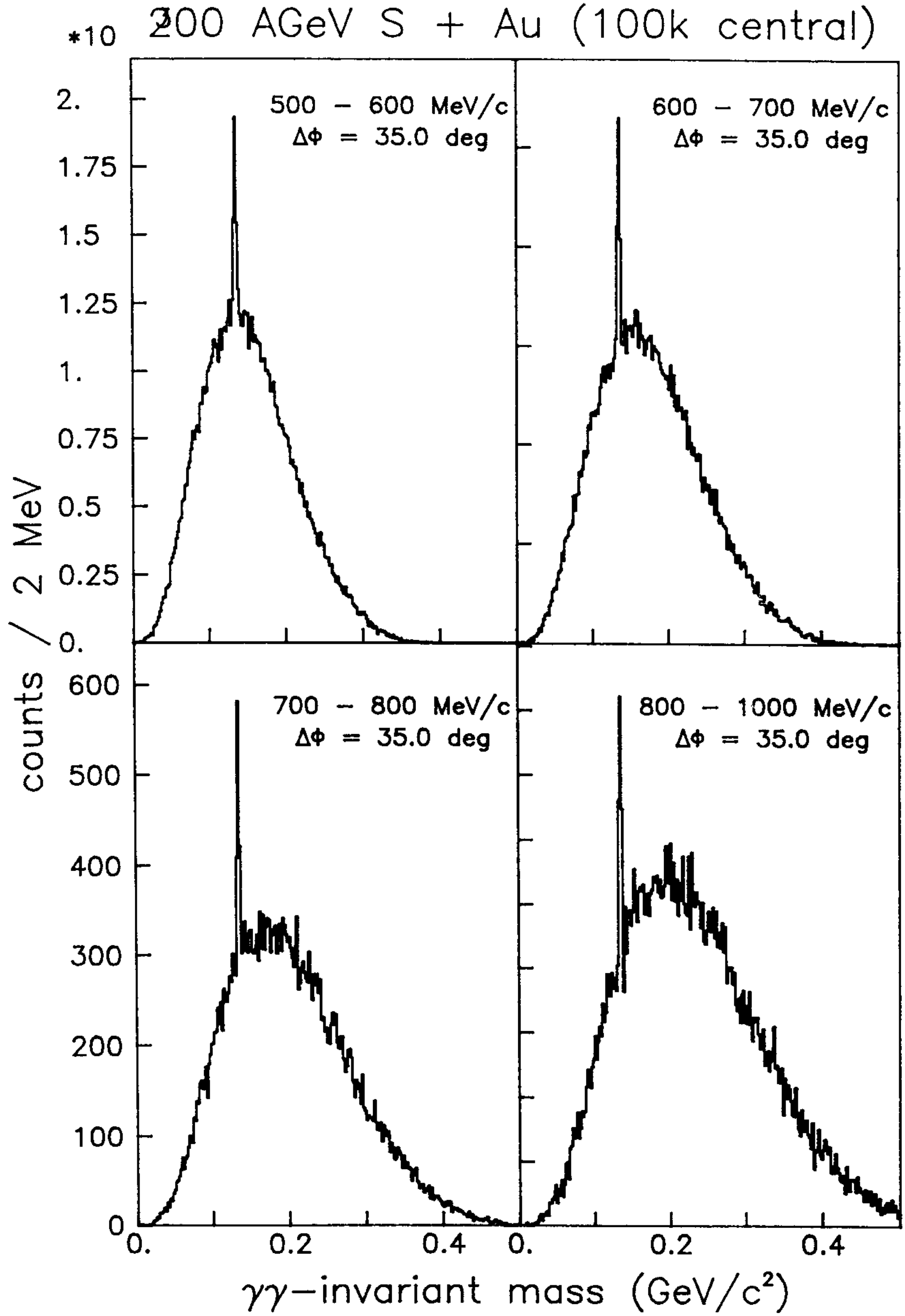
Fig. 2



cut at 9 m distance from target

Fig. 3


200 AGeV S + Au (100k central)
*10 3
*10 3
100 – 200 MeV/c
Δφ = 98.5 deg
200 – 300 MeV/c
Δφ = 70.0 deg
300 – 400 MeV/c
Δφ = 50.0 deg
400 – 500 MeV/c
Δφ = 35.0 deg
counts / 2 MeV
γγ–invariant mass (GeV/c²)
0. 0.2 0.4
0. 0.5 1. 1.5 2. 2.5 3. 3.5 4.
0 1 2 3 4 5



200 AGeV S + Au (100k central)
*10
500 – 600 MeV/c
Δφ = 35.0 deg
600 – 700 MeV/c
Δφ = 35.0 deg
700 – 800 MeV/c
Δφ = 35.0 deg
800 – 1000 MeV/c
Δφ = 35.0 deg
counts / 2 MeV
γγ–invariant mass (GeV/c²)