Soft photons at U-70 and Nuclotron

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Introduction

Experimental and theoretical studies of direct photon production in hadronic collisions essentially expand our insights about multiparticle production mechanisms. These photons are useful probes to investigate nuclear matter at all stages of the interaction. Soft photons (SP) play a particular role in these studies. Until now we have no explanation for the experimentally observed excess SP yield. These photons have low energy transverse moment $p_T < 0.1$ GeV/c, $|x| < 0.01$. In this domain their yield exceeds the theoretical estimations by 5 ÷ 8 times.

For a qualitative explanation of this effect the assumption of the formation of a cold spot of quark gluon plasma (QGP) or hadronic gas has been made in a number of theoretical papers. It is argued that a cold spot is relatively stable and radiates soft photons. SP testify the existence of a new phenomenon connected with the collective behavior of particles. One interesting option currently under discussion is the formation of a pionic condensate when a group of pions with small relative momenta can form a relatively coherent and stable system. It is known from phase shift analysis of low energy pion scattering that pions in the isotopic spin state zero have an attractive potential. In a bosonic system an attractive force is not saturated with the growth of the particle number, because all bosons can occupy one quantum state. As a consequence, the multipionic system acquires additional stability. When single pions fall in the lowest quantum state, then an intense soft photon radiation should emerge.

SP investigations at U-70 (Protvino) are prepared and proposed to study this unique phenomenon at fixed target on Nuclotron (JINR) and future collider NICA. At high hadron multiplicities available in A + A collisions at collider conditions the probability to form a cold quasistationary (hadron or parton) system is higher than in previous experiments carried out at fixed target. Photons may be detected in a TPC via conversion $\gamma \to e^+e^-$. The estimated count rate of SP is 15 s^{-1} at a beam luminosity of 10^{27} $s^{-1}cm^{-2}$. Another possibility is to implement a small (~ 10 cm^2) special electromagnetic calorimeter with a low energy threshold (~ 1÷ 5 MeV). This module can be incorporated into a barrel calorimeter.

Direct photons (DP) by definition are not a decay product of any known particle. In accordance with quantum electrodynamics they may be emitted in the process of charged particle scattering - bremsstrahlung in a parton or hadron cascade. In particular, $q\bar{q} \to g\gamma$ and $gq \to \gamma q$ parton interactions lead to photon emission.

The higher the density and the longer the system lifetime, the more DP should be emitted. The produced photons interact with the surrounding matter only electromagnetically, and therefore they bear the information on properties of the surrounding environment during whole history of evolution.

Special attention is devoted to low energy DP (SP) whose yield surpasses the theoretical predictions by 5 ÷ 8 times. This concerns $K^{+}p$ and $p\bar{p}$ Interactions at 70 GeV as well as _±p and $K+p$ interactions at 250 and 280 GeV. Some results are shown in Fig. 1. The recent results on this subject by the DELPHI collaboration are devoted to studying SP inside hadronic jets originated from the $Z^{0} \rightarrow q\bar{q} \rightarrow jet + X$ decay region. The authors claim a clear excess of SP as compared to the theoretical prediction by a factor 3 for charged and a factor 17 for neutral particles.

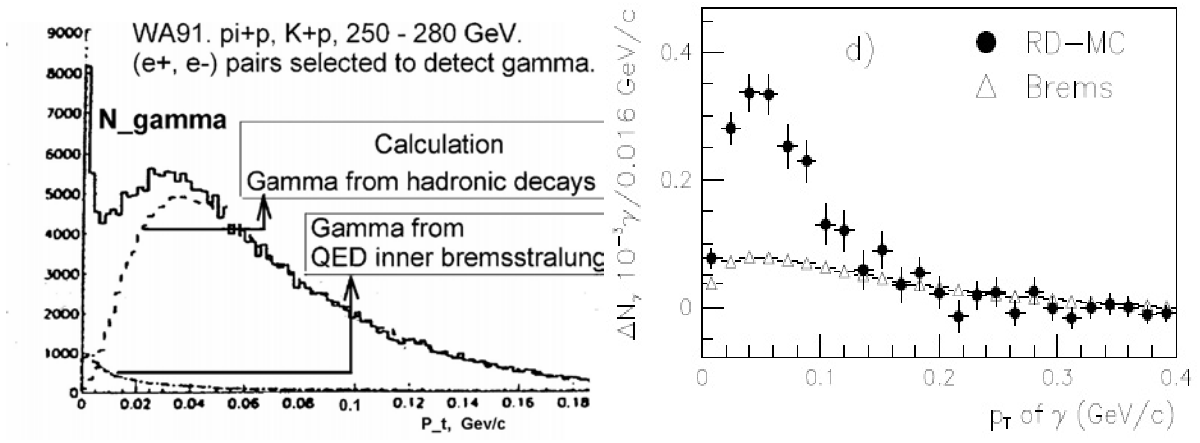

Figure 1: Left panel: SP pt spectrum. The photons from decay of known particles are shown by MC histogram. Right panel: Same as on Left panel, data. RD-MC means real data with MC data subtracted.

Photon calorimeter with low energy threshold

A specific feature of the proposed photon detector is its capability to measure low energy deposit $E_{thresh} \leq 5$MeV. Still none of the known experiments has reached such a small value of the photon energy detection. As it has been mentioned above, it is of importance for check some exotic theoretical models. We suggest constructing an electromagnetic calorimeter (ECal) from BGO scintillator (Fig. 2). The dimension of one cell should be ≈ 50 × 50 × 130 cm^3. In this case the spatial localization of a photon is ~ 5 cm. One should take in to account the transverse dimension of the photon shower ~ 5 cm. From this very qualitative consideration we conclude that the calorimeter transverse dimensions should be ~30 × 30 cm^2. Four central cells with a total area of 10 cm^2 will provide high efficiency photon detection. The longitudinal dimension should be as usual ~ 10 radiation lengths. For BGO this is ~ 12 cm. The important problem is to take into account the dissipated particle background in the experimental hall. Reduction of background may be provided by the calorimeter preshower.

The integrated cross section of the SP production in the domain $p_T < 0.1$ GeV/c, $-0.01 \leq x \leq 0.01$ is equal to 2 ÷ 4 mb/nucleon. Assuming the SP isotropic

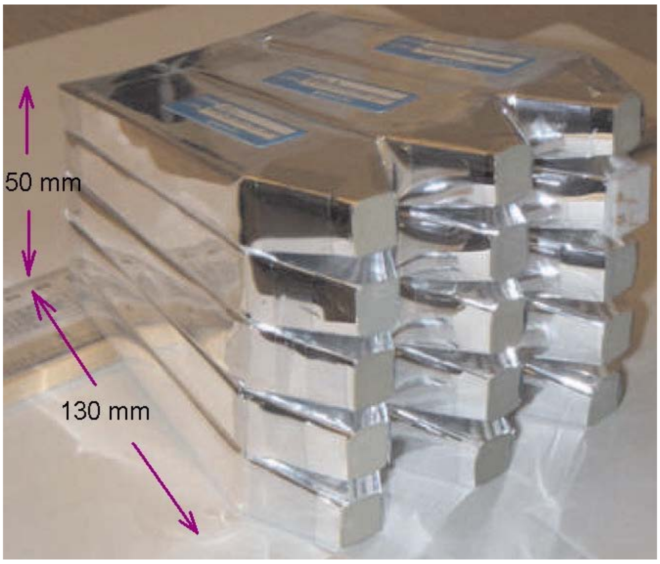

Fig. 2. Electromagnetic calorimeter prototype.

angular distribution we get an averaged differential cross section $d\sigma / d\omega$ = 0.2 mb/strad/nucleon. For a proton beam luminosity L ≅ 10^{30} cm^{-2} s^{-1} the ECal counting rate is equal to ~ 1s−1. For Au + Au collisions with luminosity L~ 1×10^{27} cm^{-2} s^{-1} the count rate is equal to ≅ $0.4s^{-1}$. During one day of runtime a statistics of ~ 5 × 10^4 SP will be accumulated. SP may convert into e^+e^- pairs in the vertex detector material and in the walls of the TPC. Thus another option is the detection of low energy e^+e^- pairs in the TPC. This leads to one order of magnitude higher statistics due to the higher angular acceptance of the TPC. But the pair detection in the TPC is subject to an additional analysis. Assuming for the photon detector effective area of 10^2 cm^2, set at a distance of 1.3 m from the target, leads to the following estimate of the DP count rate: 2 events per cycle. One week of runtime will provide a pretty good sample of SP: ≈ 2 × 10^5 events.

The distinctive features of this project.

- Photon spectra at several fixed angles will be measured. The lower edge of the spectra is ~ 5 MeV/c.
- Each SP spectrum will be collected at a certain fixed multiplicity of secondary in pp and AA interactions.
- It is planned to study both, Bose-Einstein condensation [66] and SP yield, simultaneously.

Research program.

Good knowledge of C++ programming language and the ROOT software (http://root.cern.ch) is greeted. Students it is proposed to take part to carry out at the following themes of project:

• Monte Carlo simulation of electromagnetic calorimeter prototype work by GEANT4.

• Monte Carlo simulation of soft photon registration by electromagnetic calorimeter work in GEANT4.

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Project “Thermalization” and high multiplicity study

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The number of participating students is 2÷ 3.

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