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CAN ONE DETECT A INTERMEDIATE-MASS HIGGS BOSON
IN HEAVY ION COLLISIONS?

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Due to an error in the computer program we underestimated the cross-sections both for the Higgs signal and the $b\bar{b}$ -background from photon-photon fusion. Here we give the corrected Figs. 2-4. Since the signal-to-background ratio was correct, our conclusions remain essentially unaltered, except that the necessary Pb-Pb luminosity is about one order of magnitude smaller than given in our paper. Also, the Q_0 -dependence is somewhat milder; reducing Q_0 from 60 to 55 MeV reduces the cross-sections by about 30% (20%) at the LHC (SSC).

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Fig. 4b

Fig. 4c

Fig. 2a

Fig. 2b

Fig. 3

Fig. 4a

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CAN ONE DETECT AN INTERMEDIATE-MASS HIGGS BOSON IN HEAVY-ION COLLISIONS?

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ABSTRACT

We discuss the possibility of detecting an intermediate-mass Higgs boson in ultra-relativistic heavy-ion collisions at the LHC or the SSC. We improve previous calculations of the signal cross-section by a careful treatment of the nuclear form factor in the Weizsäcker-Williams approximation. Event rates at the LHC (SSC) may be large enough to be observed if the luminosity for lead-lead collisions is 10^{29} (4×10^{27}) $\text{cm}^{-2}\text{s}^{-1}$. We calculate the physics background due to $b\bar{b}$ pair production, and show that it can be overcome in principle. We list requirements for suppressing additional instrumental backgrounds.

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It is generally agreed that one of the most important tasks for experimental particle physics is to find the Higgs boson or some other clue to the mechanism of electroweak symmetry breaking. If there is a Higgs boson with mass below ~ 40 GeV, it can be found among Z^0 decays at LEP [1]. If $m_H \lesssim 80$ GeV, the Higgs boson can be found when the LEP center-of-mass energy is increased to 190 GeV [2]. If $800 \text{ GeV} \gtrsim m_H \gtrsim 2m_{W,Z}$, the Higgs boson can be found in high-intensity high-energy pp collisions as planned for the SSC and the LHC [3]. A Higgs boson with mass between ~ 80 GeV and ~ 160 GeV presents more of a problem. It could easily be found in e^+e^- collisions beyond the planned LEP energy range [4], but projects for such e^+e^- accelerators are not as far advanced as those for the SSC and the LHC. There have been intensive studies of possible searches for such an intermediate-mass Higgs boson at high-energy pp colliders [5], which are in general difficult and may even be impossible if the dominant decay of the Higgs boson is into $t\bar{t}$. It is desirable to find other ways of looking for an intermediate-mass Higgs boson.

Recently it has been suggested [6, 7] to look for the Higgs boson in two-photon reactions in heavy-ion collisions. The idea is to counteract the factor of α^4 in the cross-section with a coherent enhancement factor Z^4 due to the electrical charge Z of a heavy nucleus N . The first indication was that the cross-section for $N + N \rightarrow N + N + H$ might be large enough to be seen at the SSC or the LHC if $m_H \lesssim 200$ GeV and the heavy-ion luminosity $\mathcal{L}_{NN} \sim (10^{27} \text{ to } 10^{29}) \text{ cm}^{-2}\text{s}^{-1}$. However, only crude models for the elastic nuclear form factors were used in a Weizsäcker-Williams approximation to the two-photon collision rate. Moreover, backgrounds to the Higgs search were not discussed. These could either be physics backgrounds, *i.e.* other production mechanisms for the same final state such as $\gamma\gamma \rightarrow b\bar{b}$ if $H \rightarrow b\bar{b}$ is the dominant Higgs decay mode, or instrumental backgrounds, *i.e.* other final states which cannot be distinguished from the Higgs decay mode because of experimental limitations. The purposes of this paper are to calculate the Higgs production rate more precisely, to study the physics background, and propose ways to overcome it. We leave the study of instrumental backgrounds to our experimental colleagues.

We first calculate the effective $\gamma\gamma$ luminosity using realistic models for the elastic nuclear form factors and improving on the Weizsäcker-Williams approximation. Most of the results we present are for Pb - Pb collisions, since a Pb source is foreseen at CERN for the fixed-target heavy-ion program. The Higgs production cross-section is then calculated in the Standard Model for different values of the top quark mass m_t . The cross-section is too small for $H \rightarrow \gamma\gamma$ and other rare decay modes to be usable: $\sigma \sim (1 \text{ to } 10) \text{ pb}$ for $m_H \simeq 100 \text{ GeV}$ to 180 GeV at the LHC, for example, and since $H \rightarrow \tau^+\tau^-$ is more difficult to observe, we focus on $H \rightarrow b\bar{b}$ decay. We show that the dominant physics

background is $\gamma\gamma \rightarrow \bar{b}b$, and that the hadronic $\bar{b}b$ background is negligible. We point out that because of the “soft” nuclear form factors, the Higgs boson is produced with negligible p_T . The $H \rightarrow \bar{b}b$ decays produce a Jacobian peak in the jet transverse energy E_T which can be seen above the $\gamma\gamma \rightarrow \bar{b}b$ background. Any signal would be enhanced by cutting on the relative rapidities of the $H \rightarrow \bar{b}b$ jets. We conclude that the physics backgrounds do not preclude observation of an intermediate-mass Higgs if $m_H \lesssim 180$ GeV and $\mathcal{L}_{Pb-Pb}(\text{LHC}) \simeq 10^{29} \text{cm}^{-2} \text{s}^{-1}$ or $\mathcal{L}_{Pb-Pb}(\text{SSC}) \simeq 4 \times 10^{27} \text{cm}^{-2} \text{s}^{-1}$. We list some requirements for suppressing the non-physics instrumental backgrounds.

We start with a description of the equivalent photon or Weizsäcker-Williams approximation[8] (WWA) for the case of two colliding nuclei. We focus on spinless nuclei[FN1] for which the electromagnetic current can be written as

$$\mathcal{J}_\mu^{em} = Ze(p + p')_\mu F(-(p - p')^2), \quad (1)$$

where Z is the charge of the nucleus and p, p' are the 4-momenta of the in- and out-going particle, respectively. The charge form factor $F(q^2)$ is the Fourier transform of the charge density ρ of the nucleus

$$F(q^2) = \frac{4\pi}{q} \int_0^\infty r \rho(r) \sin(qr) dr, \quad (2)$$

where we have assumed the nucleus to be spherically symmetric, and $\int d^3r \rho(r) = 1$. The photon density inside the nucleus $f_{\gamma|N}(z)$ can now easily be computed by postulating equality of the virtual and real photon cross-sections

$$\frac{z}{16\pi^2} \int dq^2 \frac{|\mathcal{J}_\mu^{em} M^\mu|^2}{q^4} = Z^2 (-\tfrac{1}{2} g_{\mu\nu}) M^\mu M^\nu f_{\gamma|N}(z), \quad (3)$$

where M_μ is the Feynman amplitude for some test process involving a (virtual) photon in the initial state, and z is the fractional energy loss of the nucleus. Equation (3) involves two assumptions: Firstly, we neglect the q^2 -dependence of M_μ , i.e. compute M_μ at $q^2 = 0$; this is justified since $F(q^2 \gtrsim 0.05 \text{ GeV}^2) \simeq 0$ for the heavy nuclei we are interested in, whereas the typical energy scale in M_μ is $O(100)$ GeV. Secondly, we have assumed the exchanged photon to be purely transverse; again, this is justified since the form factor forces the photon to be almost on-shell.

From Eq. (3) one finds[7]

$$f_{\gamma|N}(z) = \frac{\alpha}{\pi} \int_{z^2 M^2}^{\infty} dQ^2 \frac{|F(Q^2)|^2}{Q^2} \left[\frac{1}{z} - \frac{M^2}{Q^2} z \right], \quad (4)$$

where we have assumed $z \ll 1$. Unfortunately, computing $f_{\gamma|N}$ via Eqs. (4) and (2) requires the evaluation of a double integral for each value of z , making Eq. (4) much more unwieldy than the standard WWA used in e^+e^- collisions [9]. One way out is to use a simple parametrization for $|F(Q^2)|^2$. Here we concentrate on ^{206}Pb nuclei, since a lead source is foreseen at CERN. For this isotope, the charge density can be parametrized [10] as $\rho(r) = \rho_0 / (1 + \exp(\frac{r-c}{a}))$ (Fermi-parametrization) with $a = 0.54$ fm and $c = 6.6$ fm. Inserting this parametrization into Eq. (2) one finds that $|F(Q^2)|^2$ can be described by a Gaussian:

$$|F_{\text{Pb}}(Q^2)|^2 \simeq \exp(-Q^2/Q_0^2), \quad (5)$$

with $Q_0 \simeq 55\text{-}60$ MeV, as long as $Q \lesssim 120$ MeV. Inserting Eq. (5) into Eq. (4) finally gives

$$f_{\gamma|\text{Pb}}(z) = \frac{\alpha}{\pi} \left[-\frac{\exp(-Q_{\min}^2/Q_0^2)}{z} + \left(\frac{1}{z} + \frac{M^2}{Q_0^2} z \right) \text{Ei}(Q_{\min}^2/Q_0^2) \right], \quad (6)$$

where $Q_{\min} = z \cdot M_{\text{Pb}}$ and $\text{Ei}(x) = \int_x^{\infty} \frac{e^{-t}}{t} dt$ is the exponential integral function.

In Fig. 1 we compare the approximate form (6) for $f_{\gamma|\text{Pb}}(z)$ for $Q_0 = 55$ and 60 MeV with the “exact” result (4), using the parametrization of $\rho(r)$ described above. Obviously Eq. (6) works very well as long as the photon flux is sizeable. Several comments are in order:

- i) For all practical purposes, the photon flux is zero if $z \gtrsim 5 \cdot 10^{-4}$. In other words, the heavy nuclei never lose more than a twentieth of a percent of their energy. Using this energy loss for identification of the outgoing nuclei that took part in a two-photon reaction thus seems hopeless. On the other hand, it is crucial that one can trigger against events where the nucleus is broken up in order to eliminate QCD backgrounds. This is only possible if the detector covers the very forward and backward directions [FN2].
- ii) The spread in possible z -values is small. In order to produce a 100 GeV Higgs at the LHC the requirement $z < 5 \cdot 10^{-4}$ implies $z \geq 4 \cdot 10^{-5}$ for the photon radiated from the other lead nucleus. The Higgs boson will therefore be produced with a

small rapidity, and its decay products will emerge at large angles with respect to the beam pipe. Together with (i) above this implies that the detector will have to cover basically the whole solid angle.

- iii) Assuming a step-function form factor, $|F(Q^2)|^2 = \Theta(Q^2 - 1/R_{Pb}^2)$ with $R_{Pb} \simeq 7$ fm, as done in Ref. 6, is a bad approximation since it results in $f_{\gamma|Pb}(z) = 0$ for $z > 1.5 \cdot 10^{-4}$, which would lead to a vanishing cross-section at the LHC if $m_H > 105$ GeV.

We are now in a position to compute the relevant cross-sections. The cross-section for the production of a final state X via 2-photon fusion in the collision of heavy nuclei N is given by [FN3]

$$\sigma(NN \rightarrow NNX) = Z^4 \int dz dz' f_{\gamma|N}(z) f_{\gamma|N}(z') \sigma_{\gamma\gamma \rightarrow X}(zz's), \quad (7)$$

where s is the total invariant mass squared of the incoming NN system. For the case of the Higgs one has

$$\sigma_{\gamma\gamma \rightarrow H^0}(s) = 8 \pi^2 \frac{\Gamma_{H^0 \rightarrow \gamma\gamma}}{m_{H^0}} \delta(s - m_H^2). \quad (8)$$

Expressions for the $H^0 \rightarrow \gamma\gamma$ decay width can be found in ref. 11. We are interested in the region $m_H \lesssim 2 M_W$, where the Higgs boson dominantly decays into a heavy quark-antiquark pair. The two-photon production of the same quark flavor is thus an obvious background; an expression for the differential $\gamma\gamma \rightarrow q\bar{q}$ cross-section can be found in Ref. 12.

In Figs. 2a and 2b we show the total Higgs production cross-section as well as the invariant mass spectrum of $b\bar{b}$ pairs produced by two-photon fusion for lead-lead scattering at the LHC and SSC, respectively. Even before discussing further cuts or additional backgrounds we can draw several conclusions from these plots:

- i) The Higgs boson will be undetectable if it decays into top quarks. In this case, the background gains a charge factor of 16; moreover, the determination of the $t\bar{t}$ invariant mass will certainly be rather imprecise, increasing the background by another large factor. (Note that Fig. 2 compares a total cross-section for the signal with a differential cross-section for the background, which needs to be multiplied by an energy resolution to obtain the signal-to-background ratio.)
- ii) In the interesting region $m_H > 100$ GeV the signal cross-section is less than 10 (250) pb at the LHC (SSC). Requiring at the very least a signal of 10 ev./yr. leads to the requirement $\mathcal{L} \geq 10^{29}$ ($4 \cdot 10^{27}$) $\text{cm}^{-2}\text{s}^{-1}$ for the lead-lead luminosity at the LHC (SSC).

- iii) Especially at the LHC, where one operates closer to the effective threshold, changing the form factor parameter Q_0 by 10% can change the signal by a factor of two. Figure 1 indicated that $Q_0 \simeq 60$ MeV should be closer to the truth, but this assumes that the charge density is exactly given by the Fermi parametrization discussed above. On the other hand, increasing the mass of the top quark, which enters $\Gamma_{H \rightarrow \gamma\gamma}$, from 100 to 180 GeV changes the signal cross-section by less than 10%.
- iv) The two-photon $b\bar{b}$ background is at least not overwhelmingly large; in other words, the detection of an intermediate-mass Higgs might be possible if conditions i) and ii) above are met. The reason for the comparatively mild variation of the signal cross-section with the Higgs mass is that the $\gamma\gamma \rightarrow H$ cross-section rises roughly quadratically with m_H , with an additional spike at $m_H = 2 M_W$, whereas after mild p_T -cuts the background cross-section falls off like $M_{b\bar{b}}^{-3}$.

Before we try to decrease further the two-photon $b\bar{b}$ background we briefly discuss other backgrounds, which could potentially obscure the signal. The only other background that leaves the heavy nuclei intact and leads to a $b\bar{b}$ final state is $b\bar{b}$ production via Pomeron-Pomeron scattering. Since this is a strong interaction process it looks potentially dangerous. However, it is known phenomenologically [13] that the Pomeron couples incoherently to the valence quarks inside a hadron and also couples incoherently to the nucleons inside the nucleus. Allowing for nuclear shadowing we find that this background is proportional to $A^{4/3}$, where A is the baryon number of the nucleon under consideration, compared to the coherence factor of Z^4 for the signal. Furthermore, since the Pomeron couples incoherently to the neutrons and protons, it can take away only a fraction of the energy of a nucleon inside the nucleus, not of the whole nucleus, leading to a further suppression factor $A^{-2} \simeq 2 \cdot 10^{-5}$. Finally, since we assume that all events where one of the nuclei is broken up can be distinguished by experiment, the relevant form factors are those for Pomeron-Nucleus interactions, which we expect to be at least as soft as those for photon-nucleus interactions. Moreover, there is only a small probability that a Pomeron-Pomeron collision yields a large $-p_T$ $b\bar{b}$ pair with no detectable spectator jets. Therefore the Pomeron-Pomeron induced background is many orders of magnitude smaller than the $\gamma\gamma$ backgrounds, leaving $b\bar{b}$ production via two-photon fusion as the only sizeable physics background.

This background can be further reduced if we make use of the fact that it is peaked in the forward and backward directions, since the relevant Feynman diagrams have a light quark propagating in the t - or u -channel. We have thus required the transverse momentum

(p_T) of the b (or $\bar{b}$) to be bigger than a fraction r of the $b\bar{b}$ invariant mass $M_{b\bar{b}}$:

$$p_T \stackrel{!}{\geq} r \cdot M_{b\bar{b}}. \quad (9)$$

In Fig. 2 we show results for $r = 0.25$ and 0.4 (lower dashed curves), which reduces the background by a factor 4 and 9, respectively, whereas the signal is only decreased by 13% and 40%, respectively.

Nevertheless a clean isolation of the signal requires that $M_{b\bar{b}}$ can be measured with an accuracy of better than 10 GeV. This is *a priori* possible if both the b and the $\bar{b}$ decay purely hadronically, since otherwise energy is lost in the form of neutrinos. Since a lepton can result both directly from the decay of the b -quark and from the decay of the c -quark produced in the b -decay, this favorable situation occurs in less than 30% of the cases. Furthermore, b -quark identification, which is crucial (see below), might be facilitated if we allow the b or $\bar{b}$ to decay semileptonically (although in this case one would probably have to require the lepton to be produced directly in the b -decay, rather than from the subsequent c -decay).

One possible solution is to require only one of the quarks to decay fully hadronically, the probability of which is about 75%. In this case one can still measure the transverse momentum distribution of the b jet, and use the fact that the nucleon form factors insure production of the Higgs at zero p_T , leading to $p_T(b) = -p_T(\bar{b})$. The result for the LHC is shown in Fig. 3. Comparison with Fig. 2a shows that the Jacobian peak is as good a signal for Higgs production as the invariant mass peak. In the latter case we could use p_T -cuts to further enhance the signal-to-background ratio. Analogously, the Jacobian peak can be enhanced if we cut on the invariant mass of the $b\bar{b}$ system or, equivalently, on the rapidity of the second jet. Recall that we required one b quark to decay purely hadronically; nevertheless 50% of the time the other quark will decay partly leptonically, making a direct measurement of $M_{b\bar{b}}$ impossible. Note, however, that we are dealing with fast b -quarks, $\gamma(b) \sim 10$. All decay products will therefore get a strong boost in the direction of the original quark. It thus seems reasonable to assume that the neutrinos produced in semileptonic decays do not greatly alter the rapidity (or angle) of the observed jet + charged lepton system compared to the rapidity of the original quark. One can then use the fact that in the case of Higgs production the rapidity difference between the b and the $\bar{b}$ is fixed:

$$|y_b - y_{\bar{b}}| = \ln \left[\frac{m_H^2}{2p_T^2} - 1 + \sqrt{\left(\frac{m_H^2}{2p_T^2} - 1 \right)^2 - 1} \right]. \quad (10)$$

In Figs. 4a-4c we show the effect of requiring the rapidity of the second b quark to be not further than δy away from its target value (10). We see that now even the 100 GeV Higgs becomes visible above the background if values of $\delta y \lesssim 1/2$ are experimentally feasible. Note that application of Eq. (10) requires that one “knows” the Higgs mass in advance. From Fig. 3 we see that if $m_H \gtrsim 120$ -130 GeV a shoulder or even a peak in the p_T spectrum before cuts should allow for at least an educated guess. This hypothesis can then be tested using Eq. (10), which should transform a shoulder into a clean-cut peak (see Fig. 4b). For lighter Higgs bosons it might be necessary to systematically scan the hypothetical value of m_H and try whether cutting on the rapidity via Eq. (10) produces a peak.

Of course, once we know the transverse momentum of one b and the rapidities of both, we can easily reconstruct $M_{b\bar{b}}$ since the transverse momenta have to be balanced. This seems to contradict our statement above that semileptonic decays would make a direct measurement of $M_{b\bar{b}}$ impossible. Note, however, that in cutting on the rapidity of the second b quark we have assumed that its measurement will not be greatly distorted by semileptonic decays, *i.e.* that the direction of the missing energy more or less coincides with that of the jet + lepton system arising from the decay of this second b quark. If this is true, one could also reconstruct $M_{b\bar{b}}$ by simply scaling up the 4-momentum of the observed jet + lepton system until its transverse momentum matches the p_T of the jet in the other hemisphere. In principle, this is equivalent to the rapidity-cut described above. Which method will prove superior in practice does not only depend on how the various variables are modified by the hadronization and decay of the b -quarks, but also on purely experimental detector resolutions, and can thus not be decided by us.

So far we only have discussed backgrounds that have the same final state as the signal. We now turn to a brief discussion of other, “non-physics” backgrounds.

One particularly dangerous class of background is the two-photon production of light $q\bar{q}$ -pairs ($q = u, d, s, c$), the cross-section for which is 34 times the $b\bar{b}$ cross-section at high energies ($34 = \sum_q \frac{e_q^4}{e_b^4}$). These backgrounds are dangerous since they can only be eliminated if b -quarks can be reliably identified. A false positive identification rate of 3% will already double the background. At the same time, the b -identification has to be highly efficient in correctly identifying real b 's since the signal rate is already rather low.

Another problem might arise from the abundance of “generic” heavy ion collisions. Even though these events are expected to litter thousands of pions and other hadrons all over the detector and are thus easily identified, their cross-section should essentially be

the geometric one and thus some 11 orders of magnitude bigger than the signal. A highly efficient first-stage trigger to get rid of these events is thus crucial. Furthermore, it is hard to assess the probability that one out of 10^{11} “generic” background events by some random fluctuation imitates the signal.

Finally one might worry about hard QCD-events that actually do produce $b\bar{b}$ pairs. If only one nucleon out of each of the two colliding nuclei participates the only debris flying more or less in beam direction are the spectator jets of the two nucleons. Since the cross-section at relevant values of $M_{b\bar{b}}$ will be in the microbarn region, *i.e.* some six orders of magnitude above the signal, the detection of any one spectator jet has to have an efficiency of at least 99.9%. Whether this is feasible depends not only on the properties of the detector, but also on the as yet unknown characteristics of very energetic spectator jets.

We can summarize our main results by listing the conditions that have to be met for intermediate-mass Higgs bosons to be detectable in heavy ion collisions:

- 1) A lead-lead luminosity of 10^{29} ($4 \cdot 10^{27}$) $\text{cm}^{-2}\text{s}^{-1}$ at the LHC (SSC).
- 2) A method of identifying b -quarks that is very efficient both in rejecting most non- b events (efficiency $> 95\%$) and in identifying genuine b -events (efficiency $\gtrsim 30\text{-}50\%$, unless the luminosity can be boosted accordingly).
- 3) A method that reliably rejects “generic” heavy ion collisions, accepting at most one out of 10^{11} of these events.
- 4) A method that detects forward spectator jets that result from hard QCD collisions with an efficiency of at least 99.9%.

We leave the task of assessing the possibility of fulfilling these four instrumental conditions simultaneously to our experimental colleagues. Finally, the Higgs boson can only be detected if

- 5) the top quark is too heavy to be produced in H decays, *i.e.* $m_t > m_H/2$.

If these five conditions are fulfilled, the detection of an intermediate-mass Higgs boson in heavy ion collisions should be possible. The only serious physics-background, $b\bar{b}$ production via two-photon fusion, is roughly of the same order of magnitude as the signal and can be further reduced by cutting on the $b\bar{b}$ invariant mass and/or the transverse momentum and rapidities of the two quarks. Generally the signal-to-background ratio increases with the Higgs mass, making heavier Higgses easier to detect; this is analogous to the possibility of detecting an intermediate-mass Higgs boson via rare decay modes like ZZ^* or $\gamma\gamma$ at the

LHC and SSC, which could also be possible[5] if $m_t > m_H/2$. We conclude that heavy ion colliders, while not being greatly superior to more conventional hadron supercolliders, might well be competitive in searching for an intermediate-mass Higgs boson. However, extensive Monte Carlo studies are necessary before definite conclusions can be drawn.

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FOOTNOTES

- FN1: Since spin effects are assumed to originate from a small number of valence nucleons, they should be small even if the nucleus does have a nonzero spin in the ground state. We will focus onto the isotope ^{206}Pb , which is indeed spinless in the ground state.
- FN2: This might be a problem due to severe radiation from the breakup of beam nuclei, which is expected close to the beam directions.
- FN3: Notice that the cross-section is of order $(Z\alpha)^4$. Since $Z\alpha \simeq 0.6\text{-}0.65$ for heavy nuclei higher-order corrections can be quite important, introducing a large uncertainty into our theoretical predictions.

FIGURE CAPTIONS

1. Coherent photon density inside a ^{206}Pb nucleus. The solid line (labelled “exact”) represents the density inferred from the Fermi parametrization of the nuclear charge density, while the dashed and dotted lines are obtained from Gaussian form factors with $Q_0 = 60$ MeV and 55 MeV, respectively.
2. The $b\bar{b}$ signal from coherent $\gamma\gamma$ fusion in ^{206}Pb - ^{206}Pb scattering. The dashed lines represent the $b\bar{b}$ invariant mass distribution from the $\gamma\gamma \rightarrow b\bar{b}$ background, without and with b -jet transverse momentum cuts of $p_T > 0.25 M_{b\bar{b}}$, $p_T > 0.4 M_{b\bar{b}}$. The solid curves show the total Higgs production cross-section as a function of the Higgs mass at a) 3.4 TeV/nucleon (LHC) and b) 8 TeV/nucleon (SSC). All curves are for Gaussian form factors with $Q_0 = 60$ MeV (see text for details). For an estimate of the uncertainties of the calculation the Higgs production cross-section is also shown for $Q_0 = 55$ MeV (dotted lines).
3. Transverse momentum distribution of the b jets arising from the $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$ signal at $m_H = 100, 130$, and 160 GeV and the $\gamma\gamma \rightarrow b\bar{b}$ background at the LHC.
4. Transverse momentum distribution of the b jets from the $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$ signal and the $\gamma\gamma \rightarrow b\bar{b}$ background for a) $m_H = 100$ GeV, b) $m_H = 130$ GeV, and c) $m_H = 160$ GeV in Pb - Pb collisions at the LHC. For the background the second b jet is required to fall into the rapidity interval $y_b \pm \delta y$, where y_b is the rapidity of the second signal b jet as determined by kinematics (see Eq. (10)).

Fig. 1

Fig. 2a

Fig. 2b

Fig.3

Fig. 4a

Fig. 4b

Fig. 4c