On η_c study in resonance decays

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η_c - *production* is the "golden probe for proton structure"

(see talk *M.A.Nefedov, V.A. Saleev, A.V. Karpishkov* 28.10.2020)

For better background suppression,
η_c decays in **resonant channels** can be considered,
which can potentially give a better signal isolation (with respect to the γγ and hadronic channels) due to the **finite width** of the corresponding resonances

In this talk I will consider the case of $\eta_c(1S) \to \varphi\varphi \to 2(K^+K^-)$

The same way, for example, $\eta_c(1S) \to \rho\rho \to 2(\pi^+\pi^-)$ can be considered.
~40 times higher total branching, but ~5 times higher ρ width (150 MeV) compared to φ (32 MeV)

The main PDG parameters

- η_c (1S) Mass = 2983.9 ± 0.4 MeV ~ 2.984 GeV
- η_c (1S) Width = 32.0 ± 0.7 MeV ~ 0.032 GeV

- Branching $\eta_c \rightarrow \gamma\gamma$ = (1.68 ± 0.12) x 10^{-4}
- Branching $\eta_c \rightarrow \varphi\,\varphi$ = (1.58 ± 0.19) x 10^{-3} **!**

- φ (1020) Mass = 1019.461 ± 0.016 MeV ~1.019 GeV
- φ (1020) Width = 4.249 ± 0.013 MeV ~ 0.00425 GeV

- Branching φ (1020) → K^+K^- = (49.1 ± 0.5) %
- Thus Branching $\varphi\,\varphi \rightarrow 2\,(K^+K^-)$ = 24.1 %
- Total Branching $\eta_c \rightarrow \varphi\,\varphi \rightarrow 2\,(K^+K^-) = 3{,}8090798$ x 10^{-4}

The Study is focused on possibility of background separation

- Pythia 8.309 (p + p, √ s = 27 GeV). The main background – minimum-bias (SoftQCD:nonDiffractive)
- Channels of interest:

  g g → η_c + *g* (cross-section from PYTHIA8 $\sigma_{\eta c + g}$ **= 416 nb**) – *only this channel is considered for the moment in this talk*

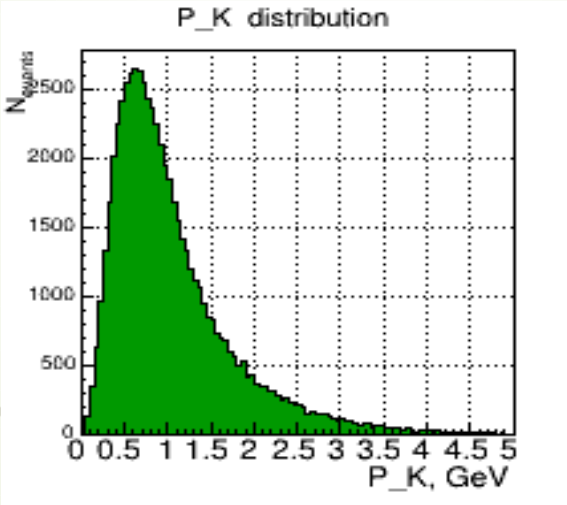
  g g → η_c (cross-section from PYTHIA8 $\sigma_{\eta c}$ **= 2230 nb**) - 5.36 times higher

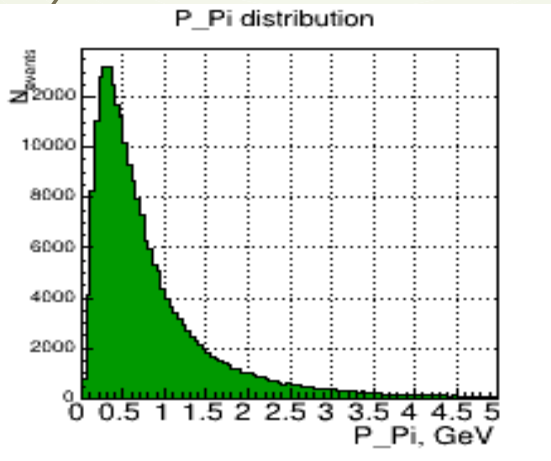
Formulae for η_c production in Pythia8 were taken as proposed by Anton Anufriev in his talk (11.04.23)

η_c is forced to decay to ***φ φ***

- Thus the final cross-section for
- **g g → η_c + *g* → *φ φ* + *g* → *2 (K^+K^-)* + g** $\sigma_{\eta c + g}$ **= 159 nb → ~1.59 * 10^5 events/year**
- **g g → η_c → *φ φ* → *2 (K^+K^-)*** $\sigma_{\eta c}$ **= ~ 2230 nb → ~8.52 * 10^5 events/year** *(10^7 sec, Lum =10^{32} /cm^2 *sec)*
- ***Thus at the most in total ~ 1.1 * 10^6 events/year***

$\pi^{\pm}$ / $K^{\pm}$ reconstruction





At **P > 1.4 GeV** we potentially can have problems with **$\pi^{\pm}$ / $K^{\pm}$** misidentification.

For the moment we have at **$P_{K\pm}$ < 1.2 GeV** — 100% identification.

At the region **1.2 GeV < $P_{K\pm}$ < 1.2 GeV** ~ 95%

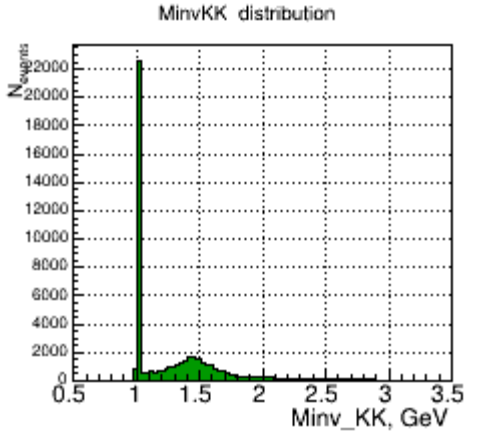
(see talks of Artem Ivanov of 6.10.2022 & 27.04.2023).

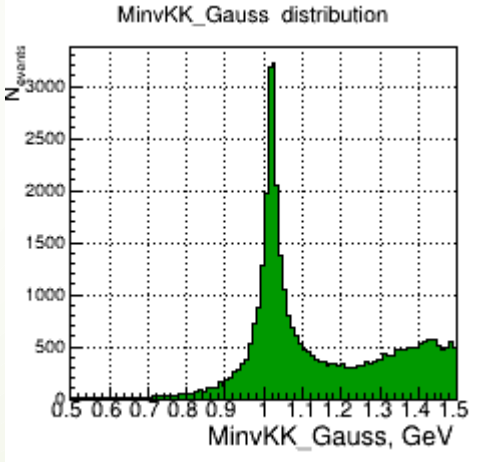
So at first approximation we considered the condition when all 4 signal $K^{\pm}$ have **$P_{K\pm}$ < 1.4 GeV**

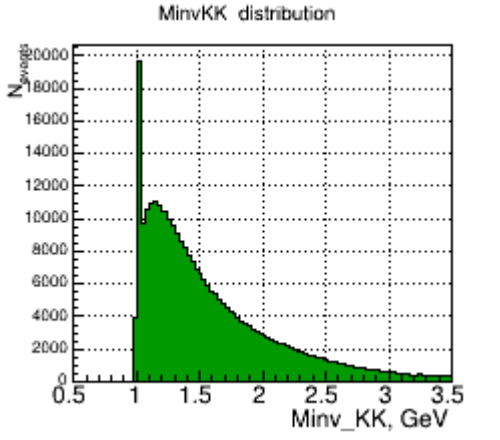
φ reconstruction

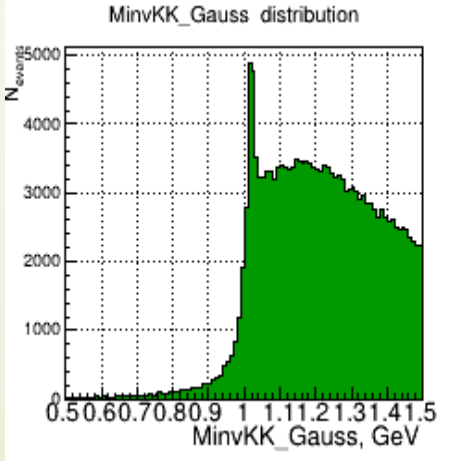
Signal

Backgd









For **φ** reconstruction we are looking for

K^+K^- combinations (**φ** candidate)

in the region

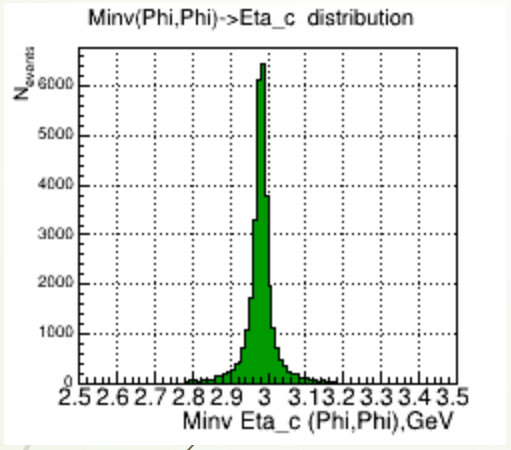
$0.92 < M_{inv}(K^+K^-) < 1.08$ GeV

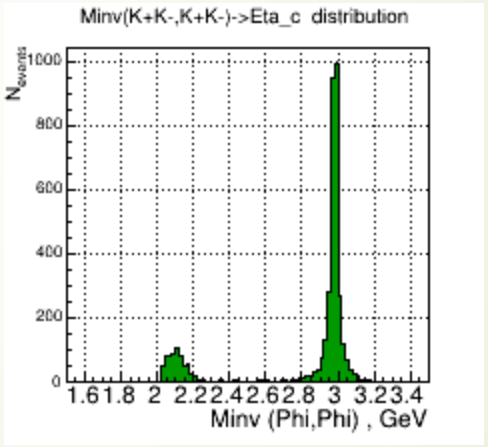
including Gauss smearing of 1.5%
for Px, Py, Pz componenta

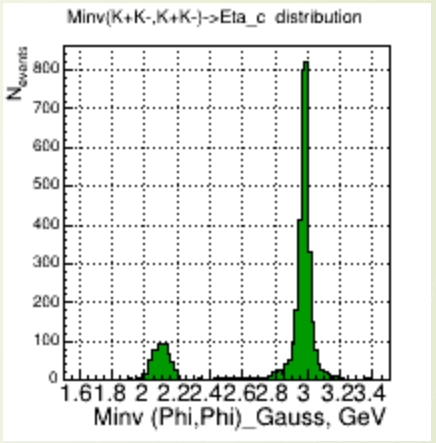
η_c reconstruction

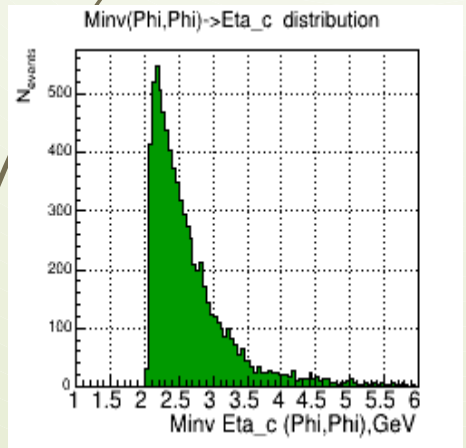
Signal

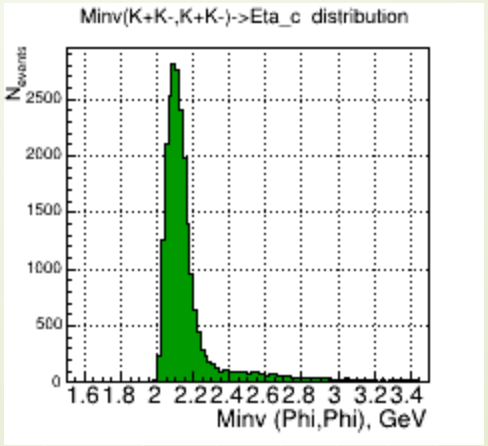
Backgd

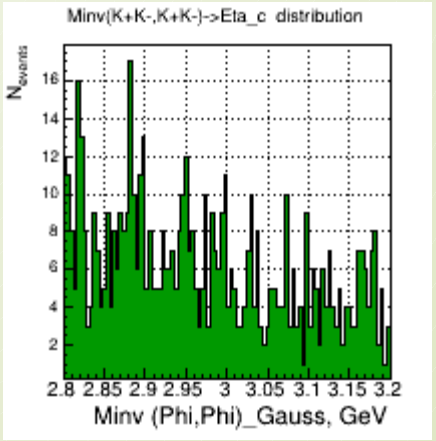












For η_c reconstruction

for the moment (!)

we are looking for exactly 2 K^+K^- combinations (φ candidates in the spread

$0.92 < M_{inv}(K^+K^-) < 1.08$ GeV)

in the region of M_{inv} η_c

$2.94 < M_{inv}(\varphi\varphi) < 3.05$ GeV

Obtained σ_{signal} = **52.27 nb**

Current results

The proposed selection criteria allowed to achieve **background suppression** *(initially 23.82 mb)* to the level of **$1.76 * 10^{-3}$ %** that corresponds to **S/B = 0.0798** for **g g → η_c + *g*** channel.

So for **g g → η_c** channel we can expect **S/B = ~ 0.4278**

Thus in total for both channels we can expect **S/B =~ 0.507**

Next steps

- To improve the algorithm to consider also the cases when we have >= 2 K^+K^- pairs
- Study production vertices of the background Kaons
- To check the case P > 1.4 GeV and $\pi^{\pm}/K^{\pm}$ misidentified combinations in this momenta region
- To play with (to minimize) the spread of $M_{inv}\eta_c$ and $M_{inv}\varphi$ determination
- Repeat the calculations for $g\ g \rightarrow \eta_c$
- To check η_c **(1S)** $\rightarrow$ **ρ ρ** $\rightarrow$ **2 (π $^+$π $^-$)** channel

So there is still a plenty of room for S/B ratio improvement

Thank you for your attention!