KEDR tagger

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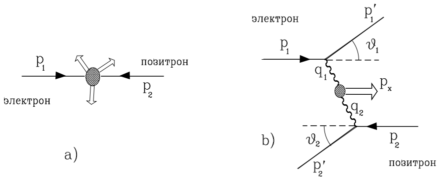
Two-photon processes

- Electron-positron colliders allow to study



a) One photon annihilation
$e^+e^- \to \gamma^* \to X$
b) Two-photon annihilation
$e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-X$

For our energy range X can be :

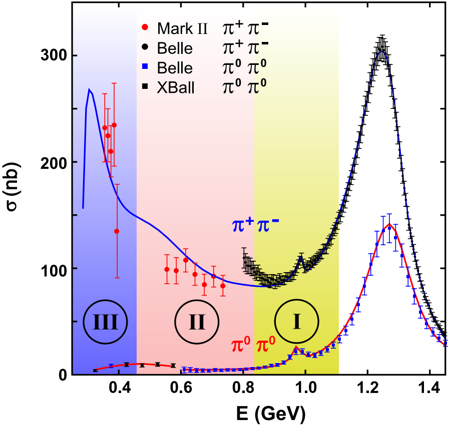
- charge pairs e^+e^-, $\mu^+\mu^-$, $\pi^+\pi^-$
- C-even resonances π^0, η, η' ...
- Other hadron systems like $\pi^+\pi^-\pi^0$...

$\gamma\gamma$ processes at the VEPP–4 collider at $2E_b = 3 - 4$ GeV

At present moment the available integrated luminosity is about 15 pb^{-1}.
With that we are looking for:

- The cross section measurements of $\gamma\gamma \to \gamma\gamma$ through resonance (π^0) and non–resonance channels.
  - The only direct measurements of π^0 two-photon width of π^0 was done at the Crystal Ball detector at 1986 year.
  - The non–resonance scattering has some interest for $g - 2$ calculations. Upper limit was set with Crystal Ball also.

- We plan to measure $\gamma\gamma \to \pi^+\pi^-$ cross section near threshold in the W range of 0.3-0.8 GeV.
  - The present experimental and theoretical results for $\gamma\gamma \to \pi^0\pi^0, \pi^+\pi^-$ are shown at the plot.
  - The $\gamma\gamma \to \pi^+\pi^-$ cross section changes about 2 times in this range of 0.3-0.5 GeV. Its measurements were done 20 years ago with accuracy about 15%.

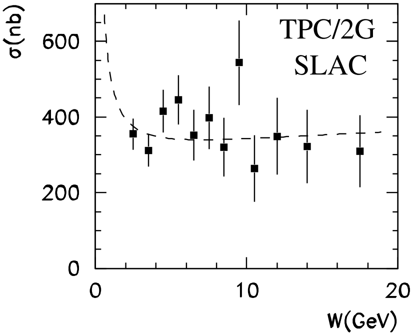


$\gamma\gamma$ processes at the VEPP–4 collider — 3

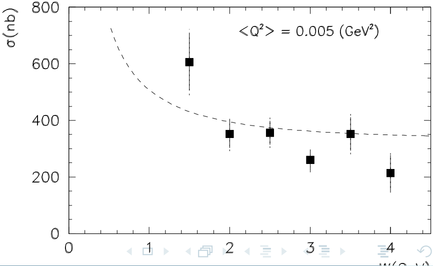
- The measurements of the total cross section for $\gamma\gamma \to$ *Any _ hadrons* in the W range of 0.3-0.8 GeV.
  - Using rather weak assumption about reaction dynamics and factorization hypothesis one can calculate its cross section as $\sigma(\gamma\gamma \to \ hadrons) = A + B/W$.
  - The parameters $A \approx 240$ nbn and $B \approx 270$ nbn·GeV are related to the γN и NN total cross sections, where N is any hardon or nucleon.
  - Most measurements have accuracy 10-20% and are related to $W > 1.5$ GeV.
  - A, B parameters can be unfolded only in the range $W < 2$ GeV.

The total cross section for $\gamma\gamma \rightarrow$ *hadrons*

- The $W_{\gamma\gamma}$ dependence of $\gamma\gamma -> $ *hadrons* from detector TPC/2gamma(SLAC) 1980-1986 years.



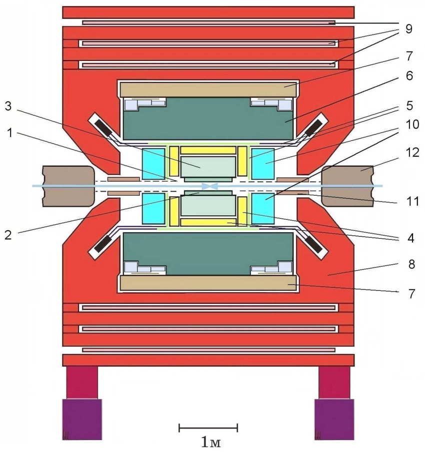
- The results from detector MD-1(BINP) 1983-1985 years



The main approaches to the $\gamma\gamma$ study

- *No-tag* — the parameters of a $X(\gamma\gamma)$ system are reconstructed with its decay products. Seems to be the most popular method. It's good for resonances and not numerous final states.
- *Double-tag* — both scattered beam particle (SE — scattered electrons) are registered. The parameters of system X can be determined independently. For small SE scattering angles $W^2 \approx 4\omega_1\omega_2 = 4(E_b - E_{e^-})(E_b - E_{e^+})$, where $\omega_{1,2}$ — virtual photon energies, E_b — beam energy, E_{e^+,e^-} — SE energies.
- An intermediate *single-tag* — allows background suppression and a kinematic reconstruction. For example, the invariant mass of $\gamma\gamma \to \pi^0$ can be calculated with
  - Two reconstructed photons in the detectors.
  - The angles of two photons and one SE energy.
  - One reconstructed photon and one SE energy.

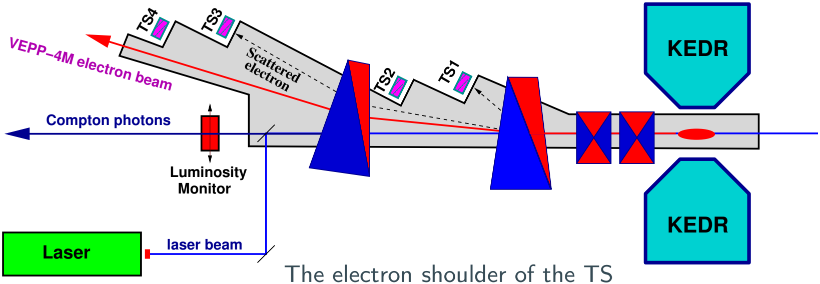
KEDR



1. Vacuum chamber.
2. Vertex detector.
3. Central drift chamber.
4. Aerogel Cherenkov counters.
5. Time of flight counters.
6. LKr barrel calorimeter.
7. CsI endcap calorimeter.
8. Muon system.
9. Superconducting coil.
10. Magnet yoke.

- Electron tagging system
- Luminosity monitor

KEDR tagging system — TS



The electron shoulder of the TS

The main idea — SE with energy $E_e = E_b - \omega$ are deflected from the beam orbit with the collider dipoles.

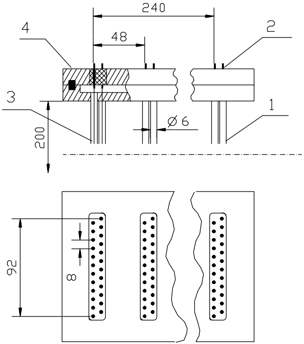
Four blocks of TS are placed along vacuum chambers at distances of 9–17 m. The block width is 90/180 mm. SE with energies $(0.4 \div 0.97) \cdot E_b$ are registered.

Collider lenses provide a focusing for some E_e energies. The collider optic was tuned to put focuses at the center of TS blocks.

KEDR tagging system. The coordinate part.

The TS was designed to work with a large Single Bremsstrahlung background – few MHz.

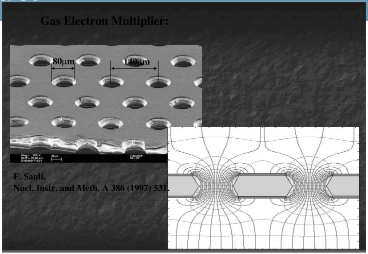
- A drift tube hodoscope is used for transverse coordinate measurements. Six double layers provide 6–12 points per track.
- The fast and radiation stable gaseous mixture was selected.
- Tube radii are 3 mm. Maximum drift time $\leq$ 30 ns.
- The coordinate resolution is 0.3-0.5 mm per tube. The limiting factor is channel-2-channel pickup noise. The track resolution at the center of the block is 0.2-0.3 mm.



Suffering factors

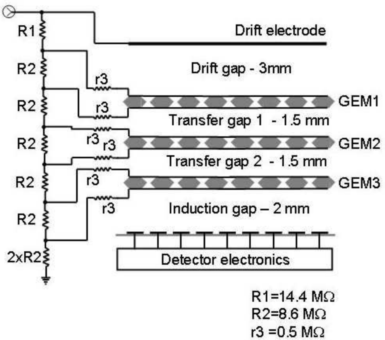
- There is no vertical coordinate measurements.
- This coordinate resolution is provide essential issue to the energy resolution.

KEDR tagging system. Upgrade.



To improve TS coordinate resolution 8 triple-GEM detectors were added to the system.
The coordinate resolution for $X_{tr} \approx$ 75 μm and about 220 μm for the vertical coordinate. The 2D reconstruction efficiency is 92-95%.
This GEM system was included to the KEDR DAQ at 2010 year.

This is the first GEM-detector at the experiments in the e^+e^- colliders.



TS energy resolution

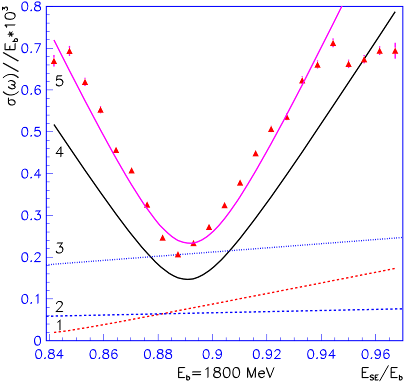
Magnetic lenses makes SE kinematics rather tricky but drastically improve energy resolution. For the zero scattering angle of SE at the collision point X_0 its coordinate is

$$X_{tr} = a\frac{E_b}{\tilde{E}_{SE}} + b + X_0 = \frac{E_b}{E_{SE}} + b,$$

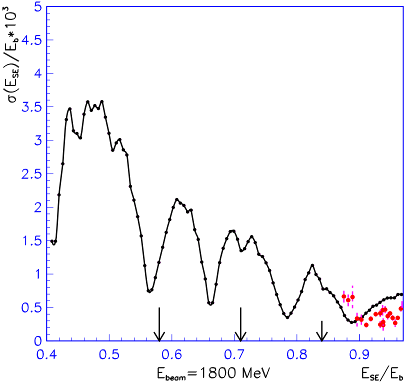
$\tilde{E}_{SE}$ — true SE energy, a, b — geometrical parameters. E_{SE} is the measured SE energy. If $\tilde{E}_{SE}$ is close to focusing energy — the scattering angle influence is suppressed.
The photon energy is calculated as

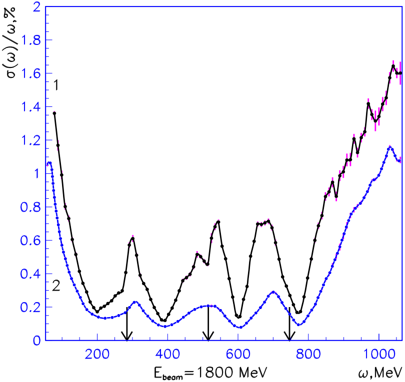
$$\omega = E_0 - \tilde{E}_{SE} \approx E_b - E_{SE},$$

where E_0 — initial SE energy. It is differ from E_b due to the beam energy spread.
For the VEPP-4 optics there is a strong correlation between X_0 and $(E_b - E_0)$. $E_{SE} - \tilde{E}_{SE}$ shift is partially compensate by $(E_0 - E_b)$ shift.



The issues to the virtual photon energy resolution. 1 — beam energy spread, 2,3 — track accuracy 0.1 and 0.3 mm, 4 — SE angle spread, 5 — the resulting resolution.





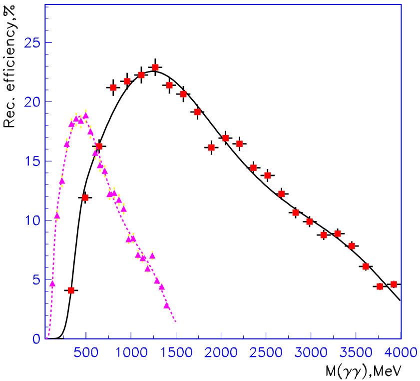
The expected scattering electron energy resolution $\sigma(E_{SE})/E_b \cdot 10^3$ for 1800 MeV collider energy.

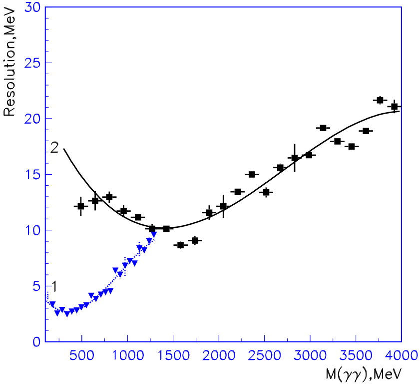
Red points shows the experimental resolution recently measured with the Compton backscattering of laser photons.

The expected photon energy resolution $\sigma(\omega)/\omega$,% .

1 – Virtual photons from two-photon processes.

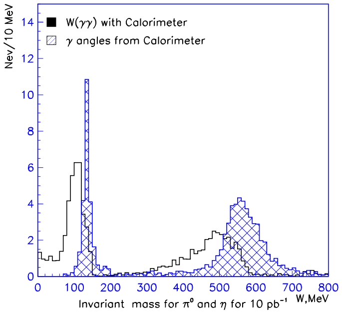
2 – Real photons from the Single Bremsstrahlung process. Excellent place for calorimeters testing



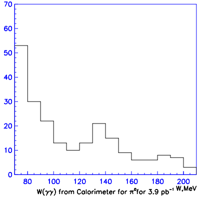


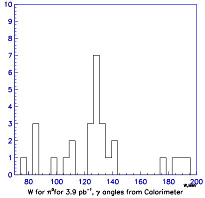
TS efficiency for double-tagged events for collider energy 1800 and 5000 MeV.

TS invariant mass resolution for double-tagged events.



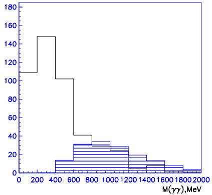
MC simulation. The expected signal of $\gamma\gamma \rightarrow \pi^0, \eta \rightarrow \gamma\gamma$ for 10 pb^{-1}. Open histogram — 2 photons in the endcap calorimeter. Hatched histogram — cluster angles and one SE energy.

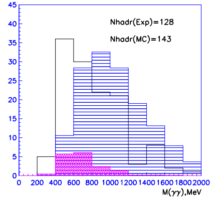




Experiment, 7 pb^{-1}. Signal is very small. We expect some trigger inefficiency. Trigger was modified recently.

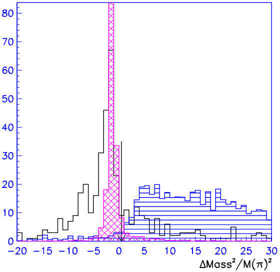
TS for two-photon physics. Illustration–2





Experiment, 3 pb−1. Selection criteria for $\gamma\gamma$ events: $\geq 3particle{+}double\_tag$.

A large background of $\gamma\gamma \to 2charged$ is seen on the upper plot.



Missing mass is calculated with both SE + 1 *charged*.

The histogram shows the distribution for $\Delta = \frac{M^2_{mis} - m^2_\pi}{m^2_\pi}$.

The selection $\Delta > 0$ allow remove $\gamma\gamma \to 2char$ background (lower plot).

Conclusion.

- The tagging system for KEDR detector was upgraded.
- Its excellent energy resolution was confirmed.
- Usage of the tagging system essentially enhance an ability to analyze two-photon events.