Experimental Comparison of Performance of Various Fluorescent Screens Applied for Relativistic Electron/Positron Beam Imaging

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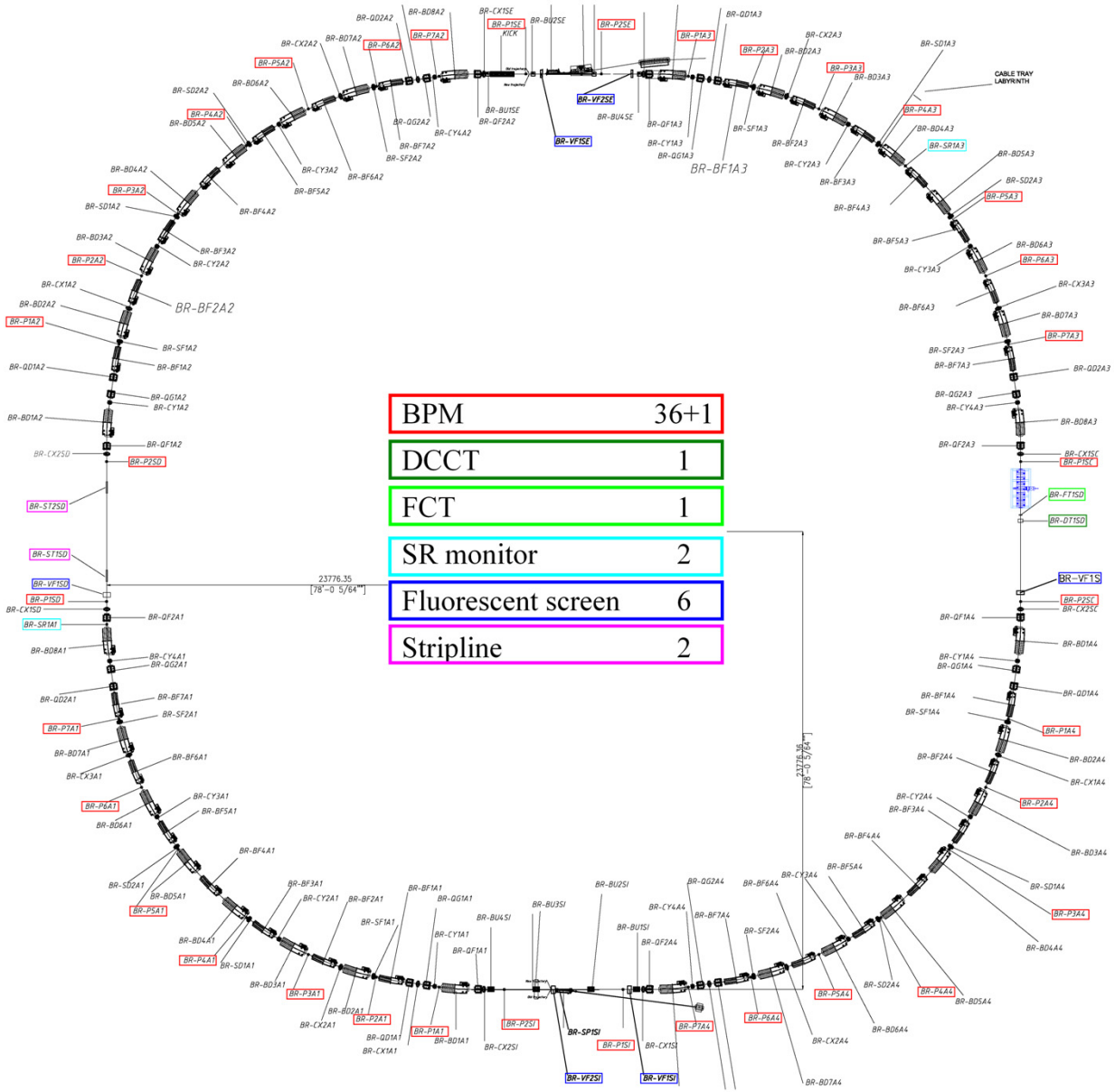
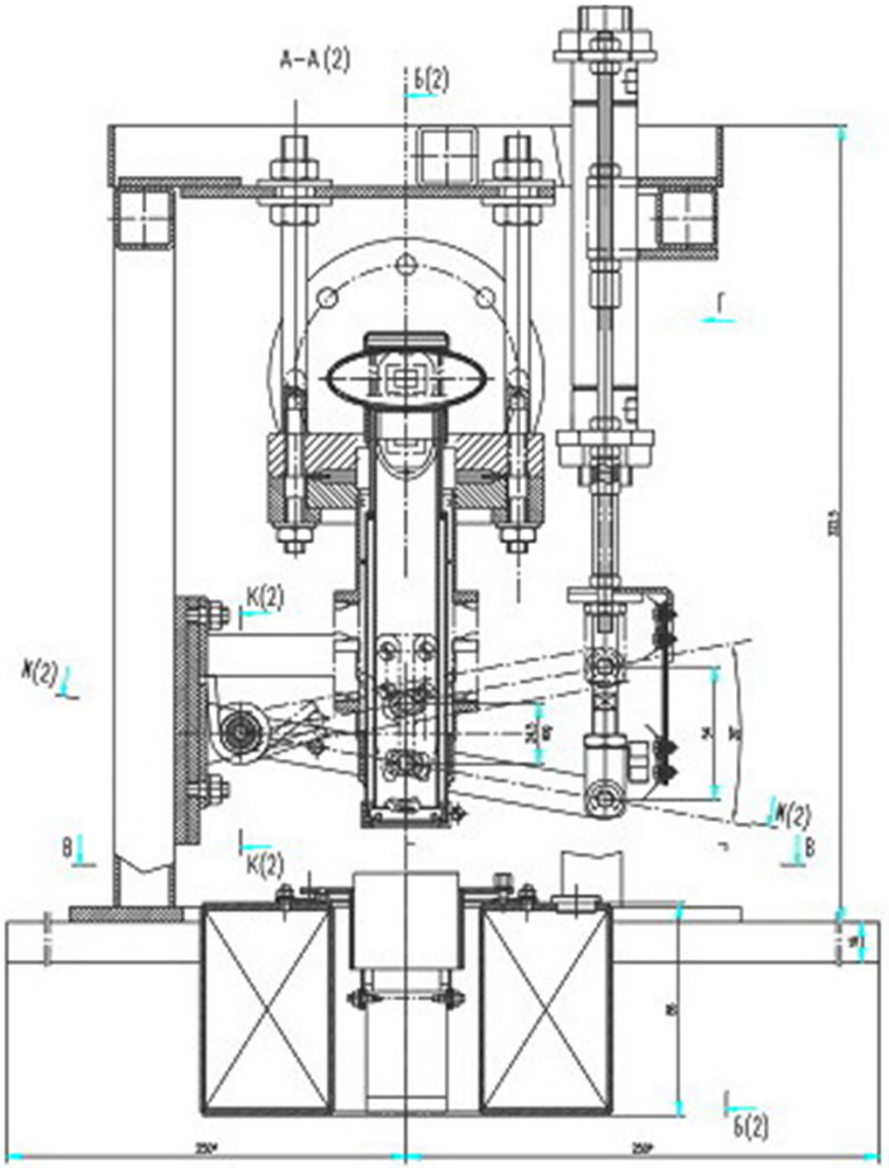
Motivation

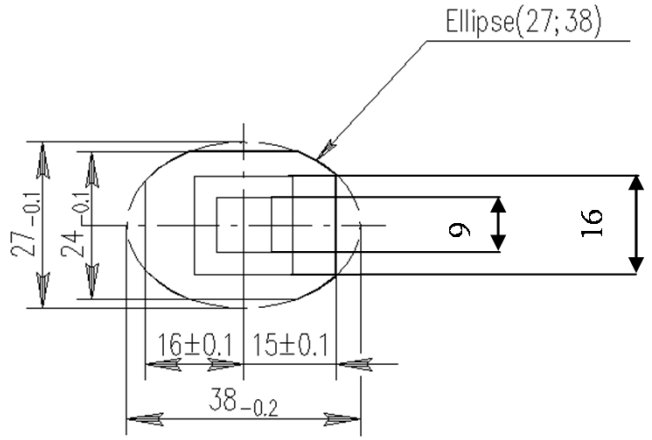


This paper was motivated by necessity to create a diagnostic system for the booster of NSLS-II SR source (Brookhaven, USA).

Booster diagnostics contains 6 fluorescent screens, which are used to close the first beam turn and to monitor the transversal dimensions and position of a beam during injection and extraction

Flags design



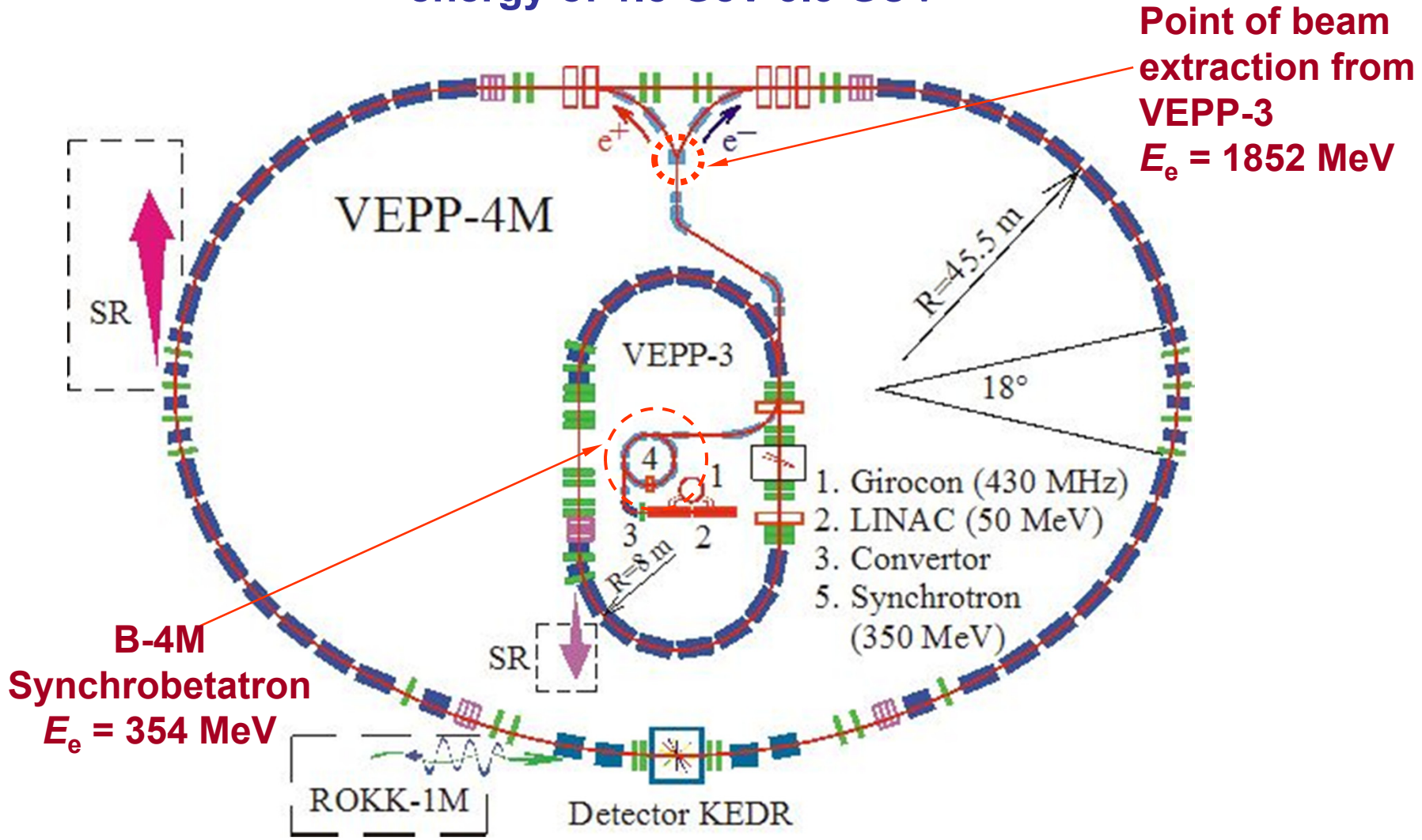


(YAG:Ce) screen are manufactured by Crytur Company (Czech Republic).

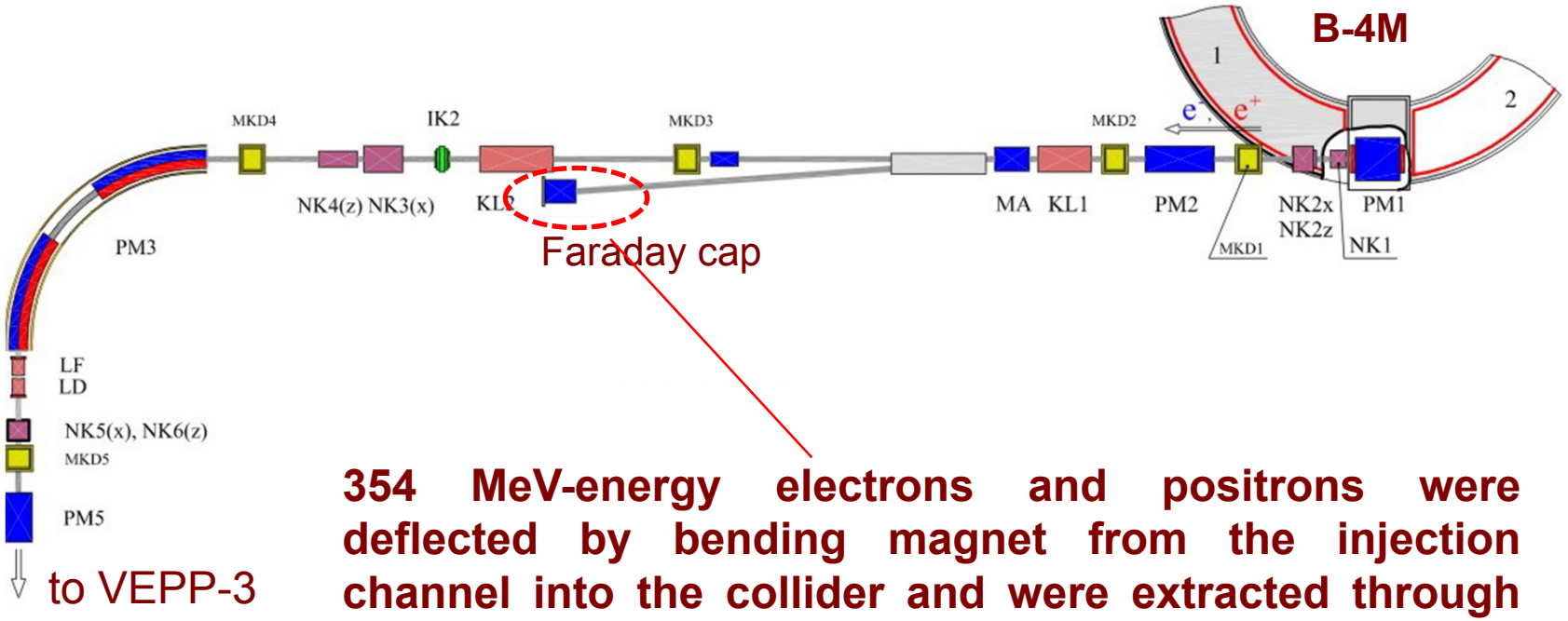
The thickness of the screen and pattern lines is 0.1 mm.

Source of electron and positron beams:

VEPP-4M is an electron-positron collider operating now at the energy of 1.8 GeV-3.5 GeV



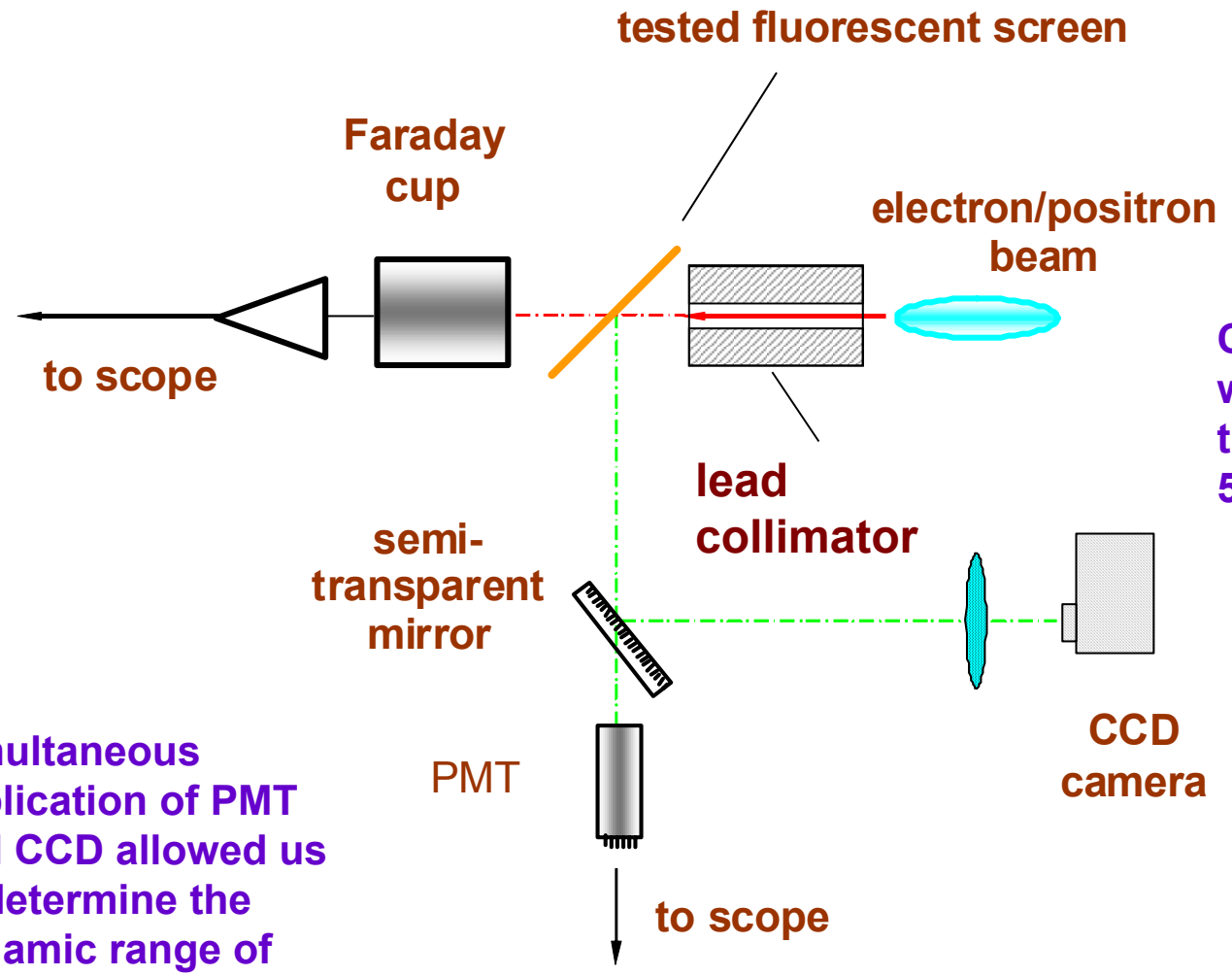
Scheme of beam extraction from synchrobetatron B4-M



354 MeV-energy electrons and positrons were deflected by bending magnet from the injection channel into the collider and were extracted through the separation foil into the atmosphere.

The amount of electrons in one bunch is up to 10^{10}, and the number of positrons is two orders less.

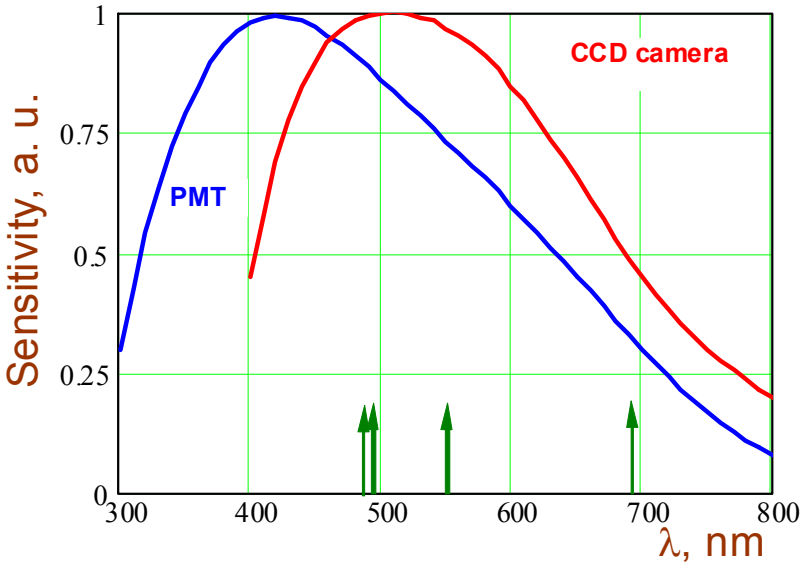
Experimental setup



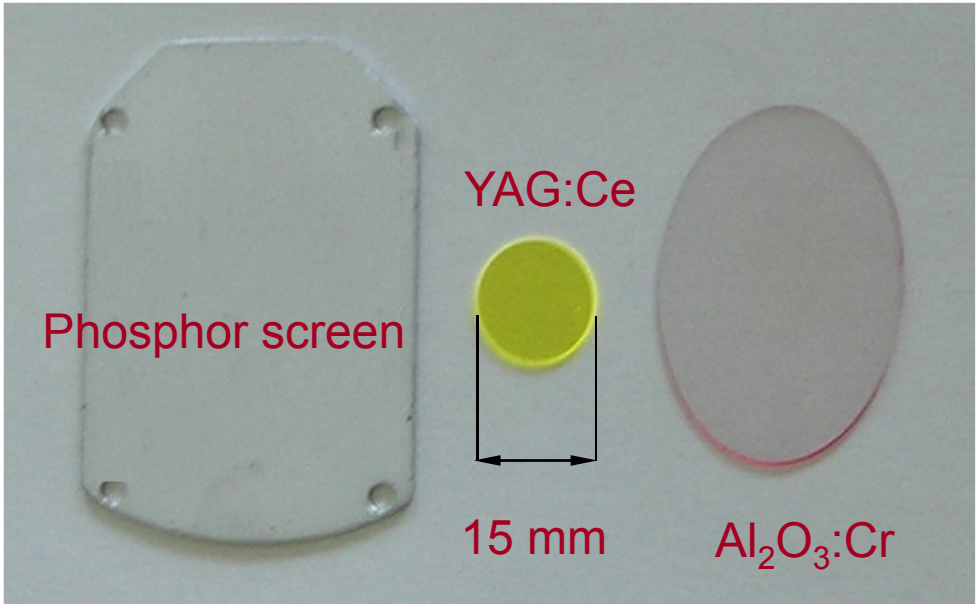
CCD was calibrated with a laser diode at the wavelength of 532 nm

Simultaneous application of PMT and CCD allowed us to determine the dynamic range of both devices

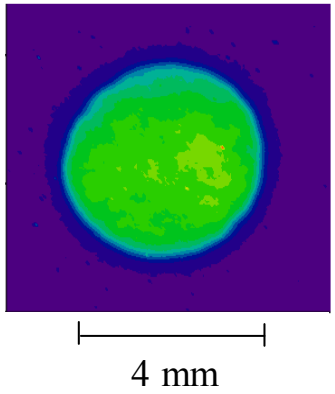
Experimental setup



Spectral response of PMT and CCD camera



Examples of the tested screens



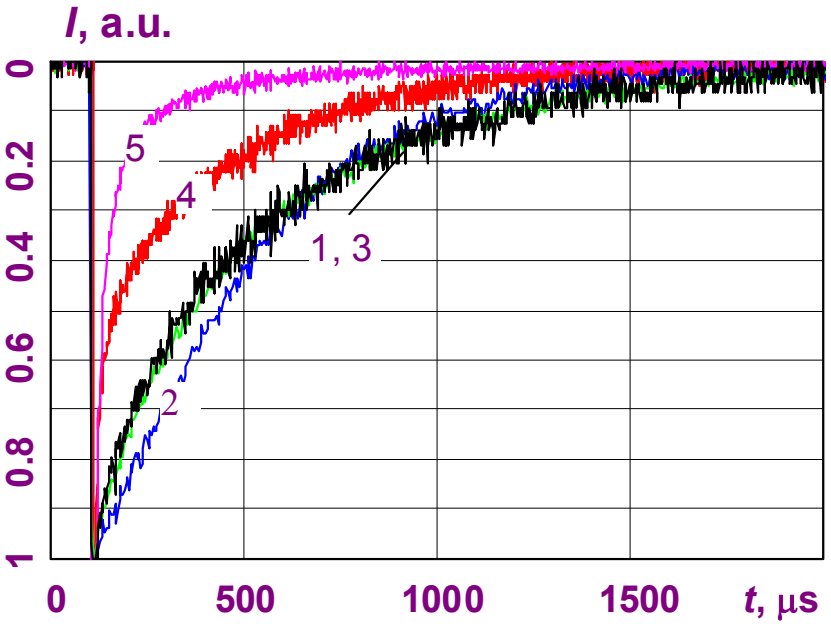
Typical beam image registered with CCD camera.
The intensity of light is represented in color scale

Phosphor screens

Phosphor	Light output colour	Timing (10%), mks
1. ZnS	Green	1250
2. Gd_2O_2S:Tb	Green	750
3. (ZnS, CdS):Ag	Green	1250
4. Y_2O_2S:Tb	Blue	1000
5. Gd_2O_2S:Eu	Red	250

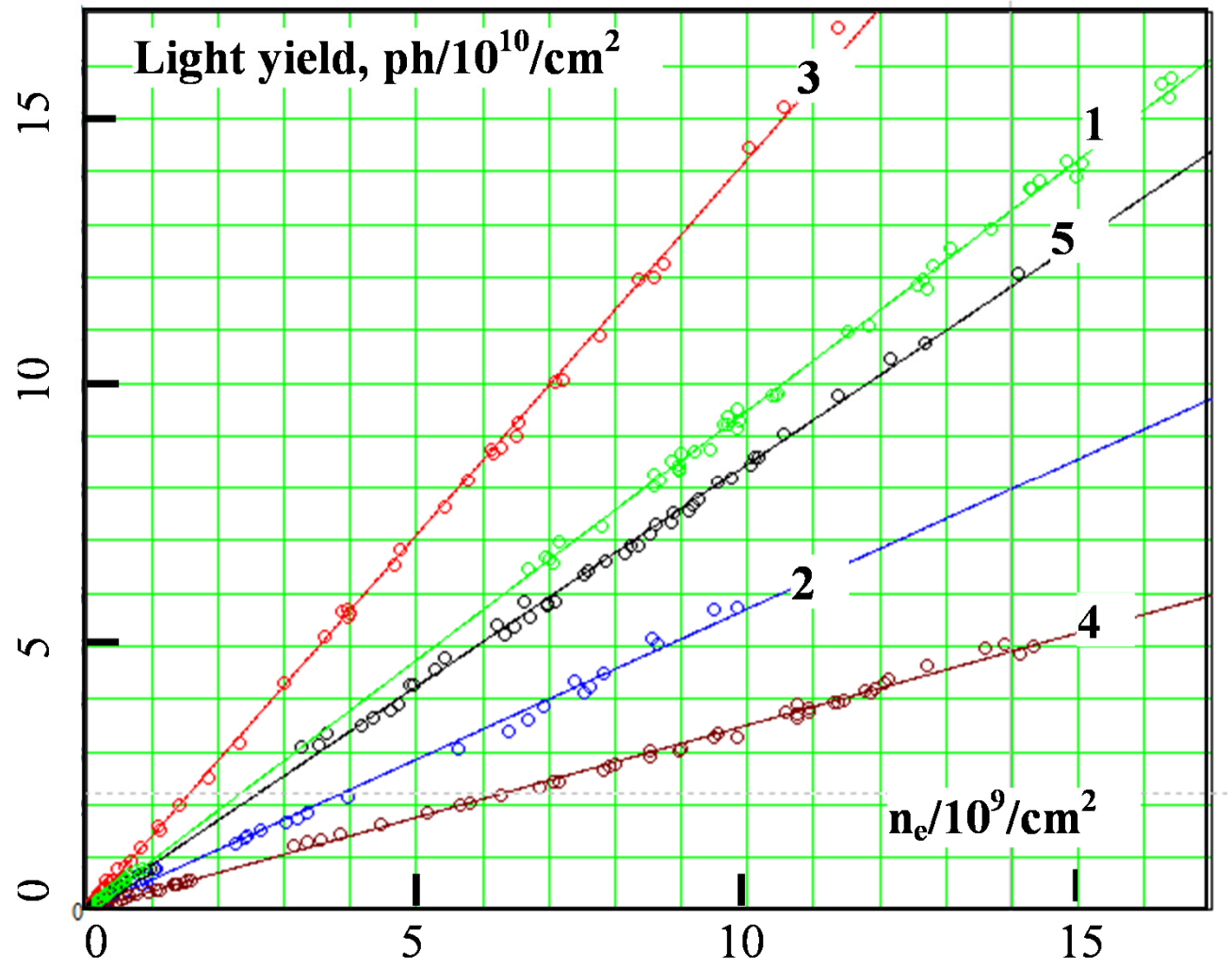
Substrate: 1-mm aluminum plate

Grain size: 2-3 μm



The timing of the phosphors measured experimentally

Light yield of the phosphors (CCD data)



1: ZnS

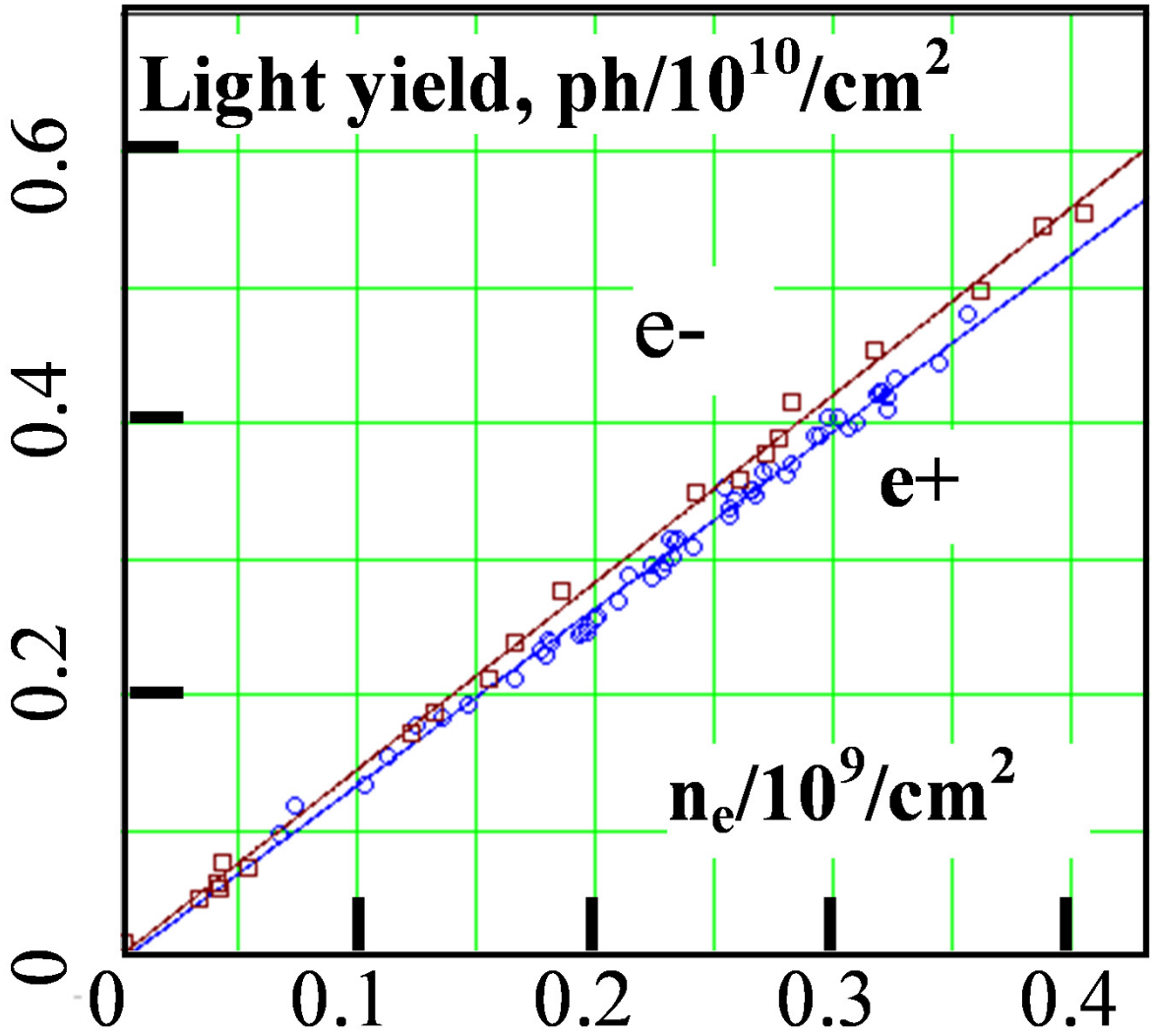
2: Gd_2O_2S:Tb

3: (ZnS, CdS):Ag

4: Y_2O_2S:Tb

5: Gd_2O_2S:Eu

Light yield of (ZnS, CdS):Ag phosphor under positron impact

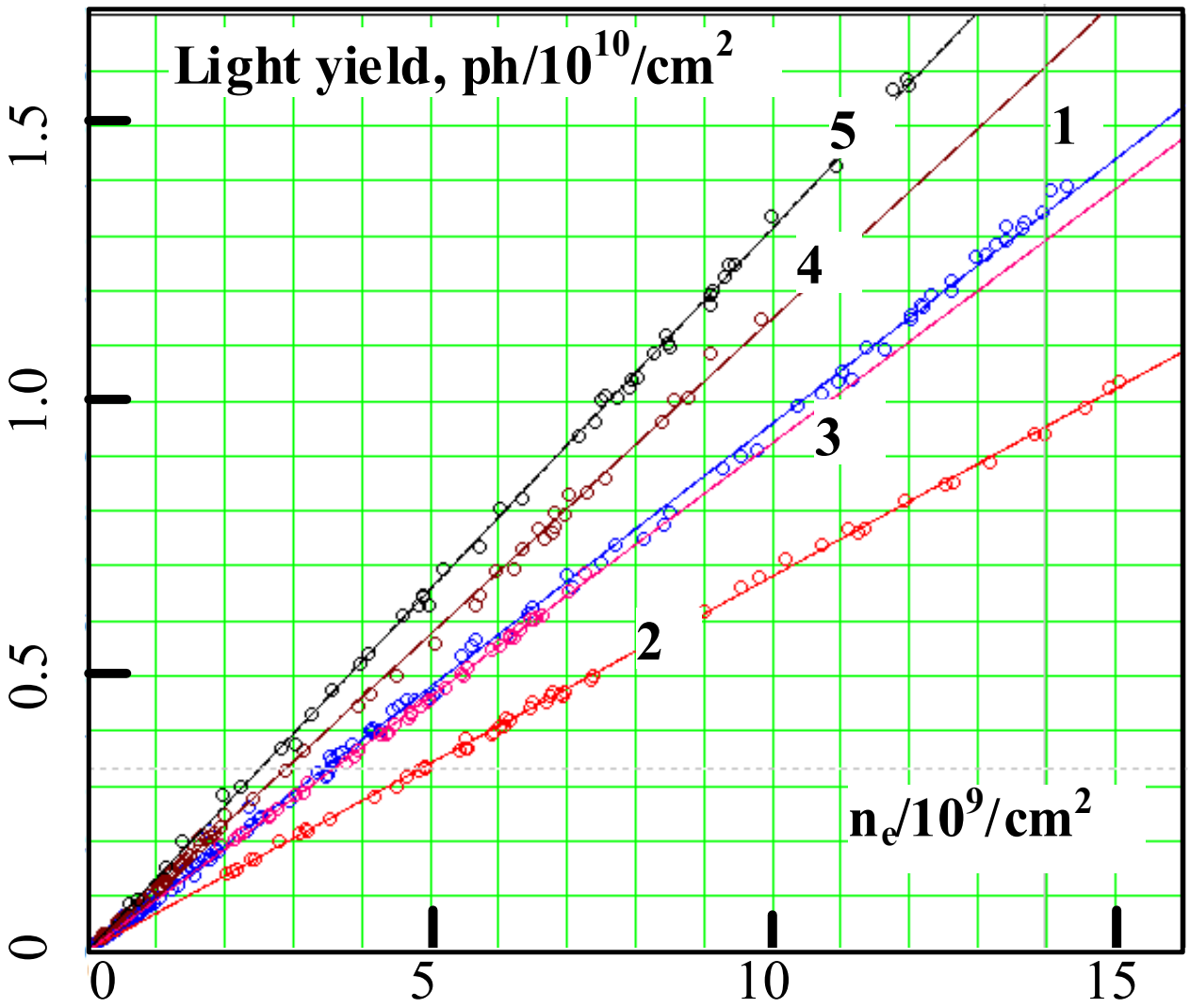


Expectedly, no difference within the accuracy of the experiment was found

Some properties of the crystals used as fluorescent screens

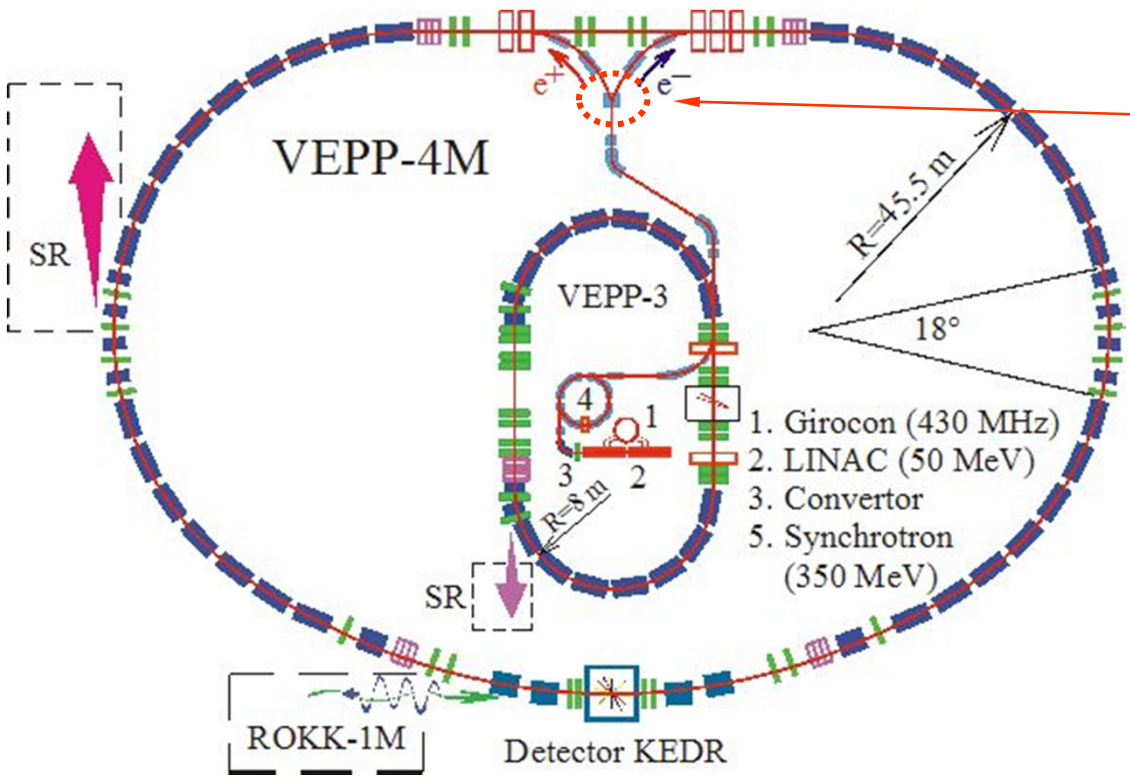
Material	YAG:Ce	Al_2O_3:Cr	ZWO	BGO	CWO
Physical Properties					
Chemical Formula	$Y_3Al_5O_{12}$	Al_2O_3 (ruby)	$ZnWO_4$	Bi_4GeO_4	$CdWO_4$
Density g/cm^3	4.57	3.97	7.8	7.13	7.9
Hydroscopic	no	no	no	no	no
Mechanical Properties	Excellent	Excellent	Satisfactorily	Good	Satisfactorily
Index of Refraction	1.82	1.57 (589 nm)	2.1-2.2	2.15	2.25
Luminescence Properties					
Integrated Light Output, γ-rays, (%NaI:Tl)	15	?	20-25	15-20	35-40
Decay Constant (ns)	70	5000	10-20 000	300	5000
Radiation length, cm	3.5	7.5	0.85	1.1	1.06
Wave Length of Max. Emission (nm)	550	694	480 (spans between 350 and 650)	480	490

Light yield of the crystals vs beam charge



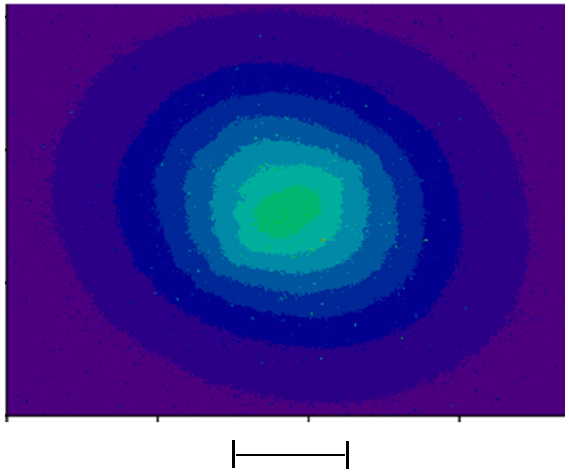
1. YAG:Ce
2. Al_2O_3:Cr
3. ZWO
4. BGO
5. CWO

Measurement of light yield at E = 1852 MeV



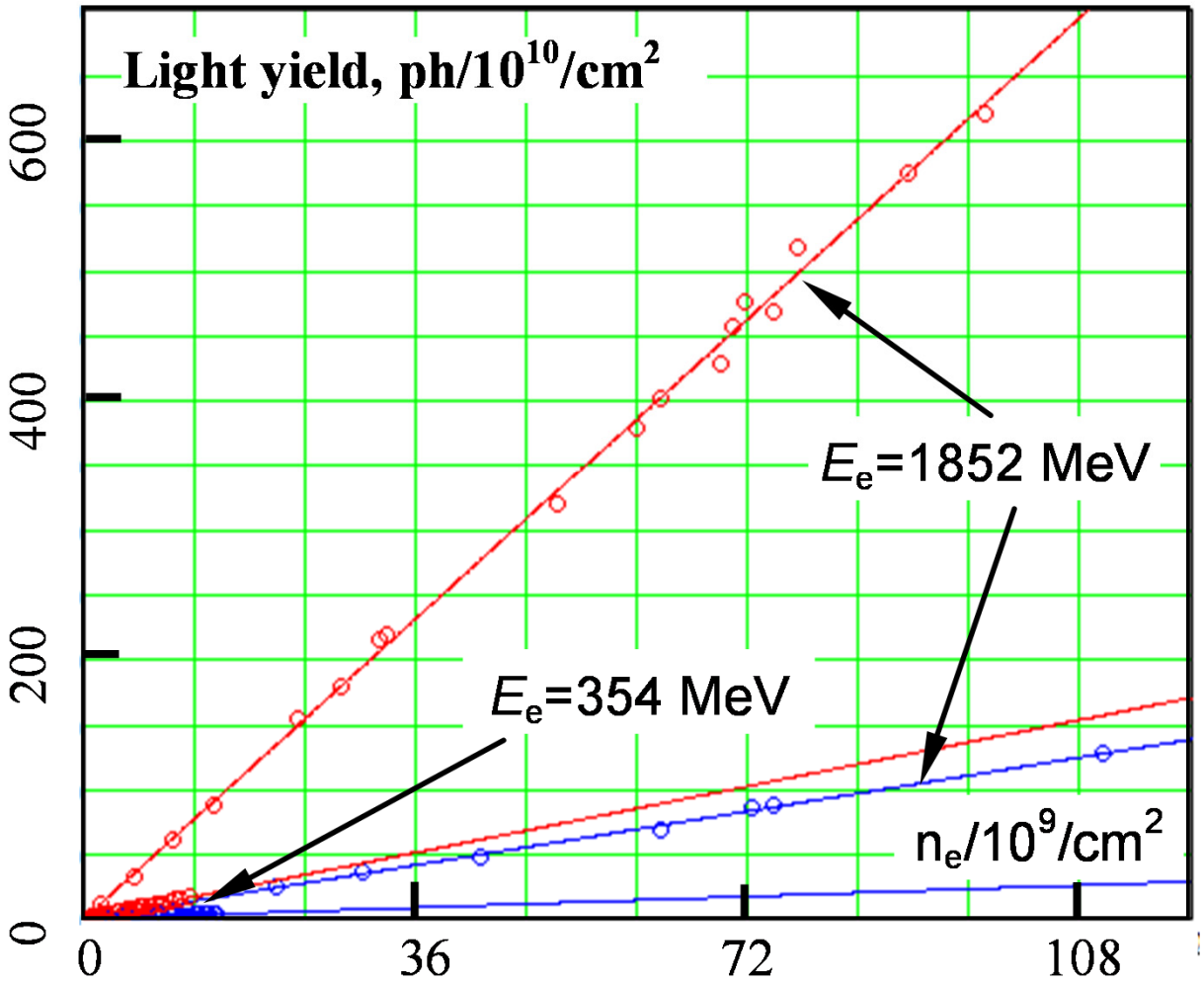
Point of beam extraction from VEPP-3
E_e = 1852 MeV
$n_e \cong 10^{11}$

Image of the beam passing through 2-mm stainless steel



8 mm

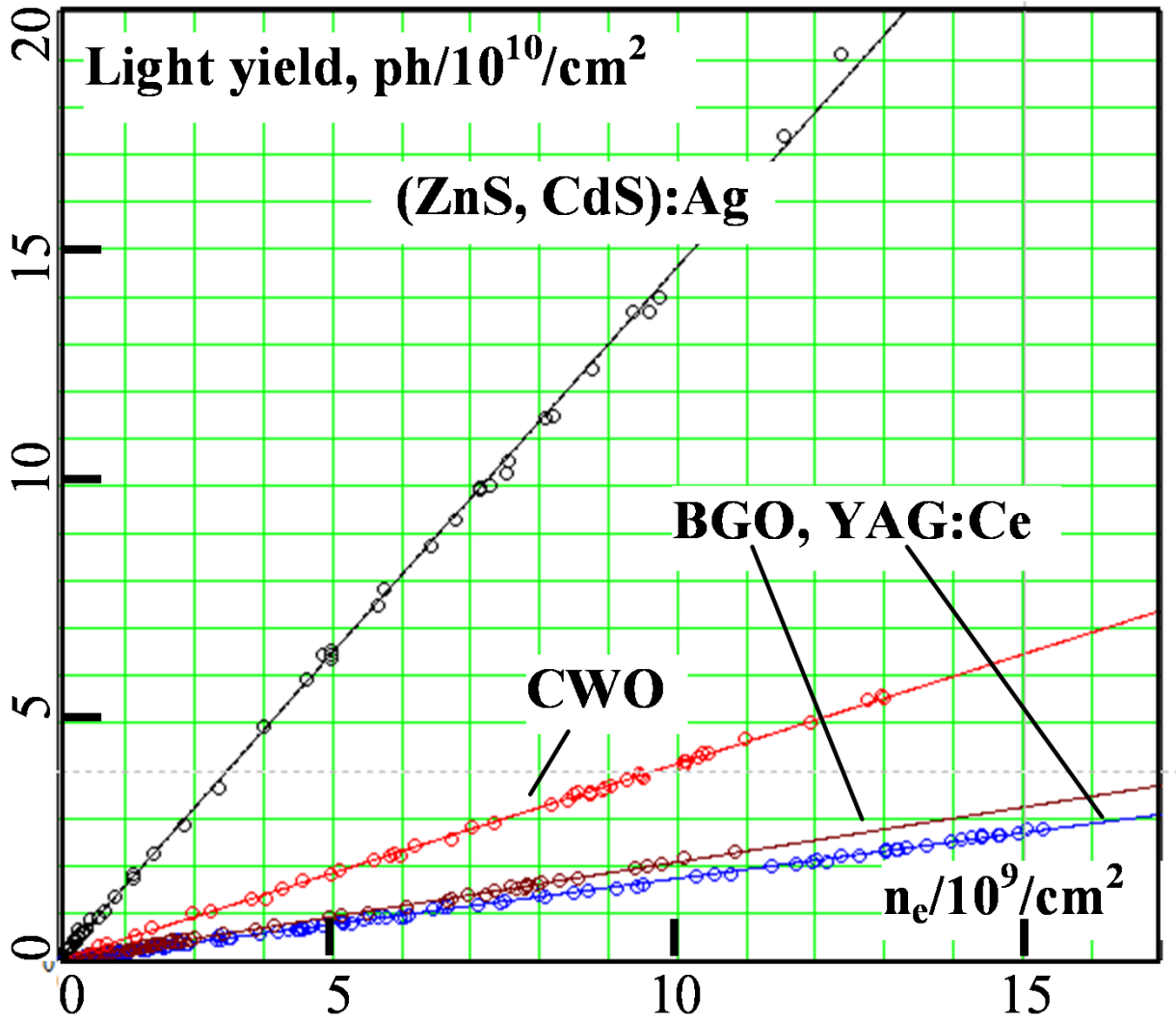
Light yield of (ZnS, CdS):Ag phosphor and YAG:Ce crystals under influence of electron beam with different energies



(ZnS, CdS):Ag

YAG:Ce

Comparison of light yield of phosphor and crystals



Conclusion

The comparison of light yield for 5 kinds of phosphors and 5 kinds of crystals under influence of electron beam were done. The light yield of all tested materials was linear up to the beam density about 10^{11} e^-/cm^2.

No signs of saturation of light yield were found.

Thank you for your attention!