

Procedures of absolute calibration of the Space Solar Patrol instrumentation at the Synchrotron radiation source

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The background of the slide is a photograph of the Space Solar Patrol satellite in orbit above Earth's atmosphere. The satellite is a complex structure with various instruments and solar panels. The Earth's horizon is visible at the bottom of the frame, showing a blue and white gradient.

CALIBRATION OF THE APPARATUS OF THE SPACE SOLAR PATROL USING SINCHROTRON RADIATION

Spectral range: 0.25 - 122 nm;

Accuracy - about 10%

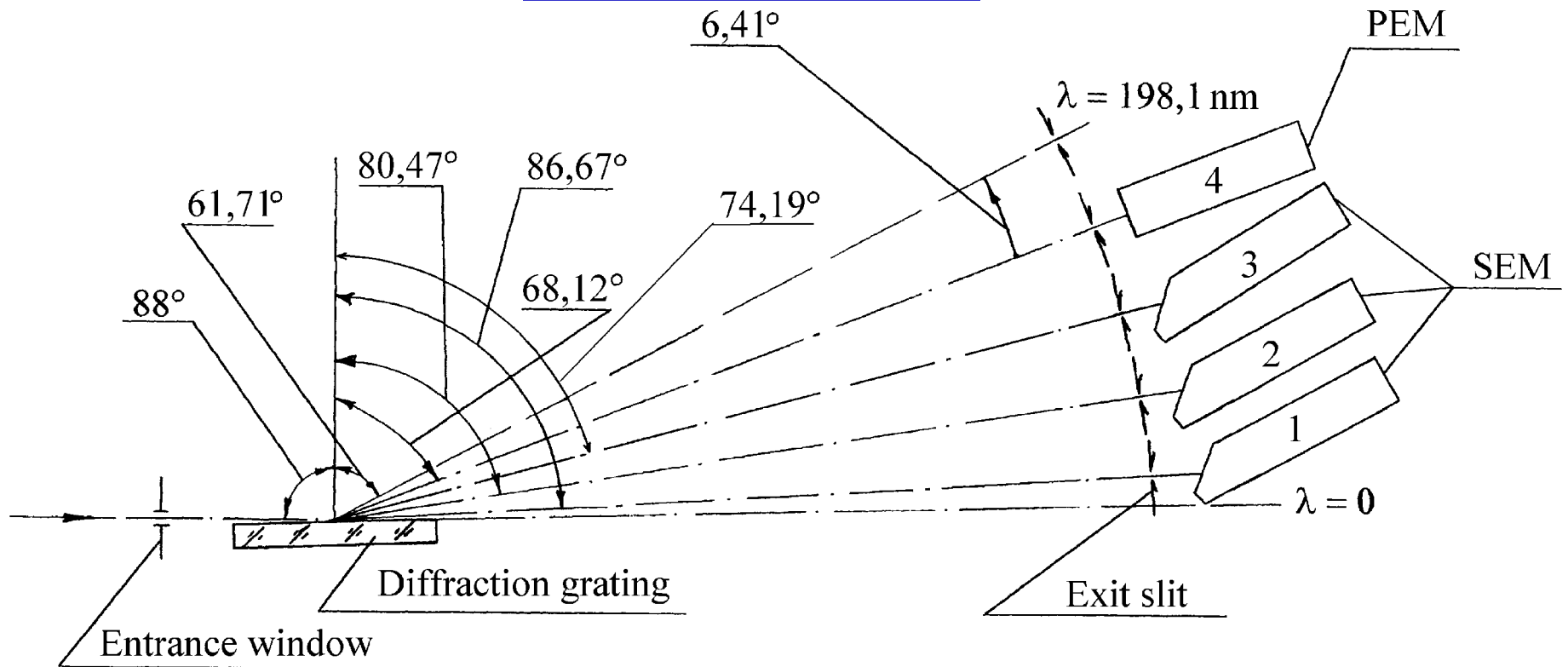
Including:

- **5-channel VUV spectrometer (16 - 122 nm)**
- **4- channel X-ray spectrometer (1.8 -122 nm)**
- **radiometer (0.25-122 nm)**

4- channel X-ray-EUF spectrometer (1.8 -122 nm)



OPTICAL SCHEME OF THE X-RAY-EUV SPECTROMETER



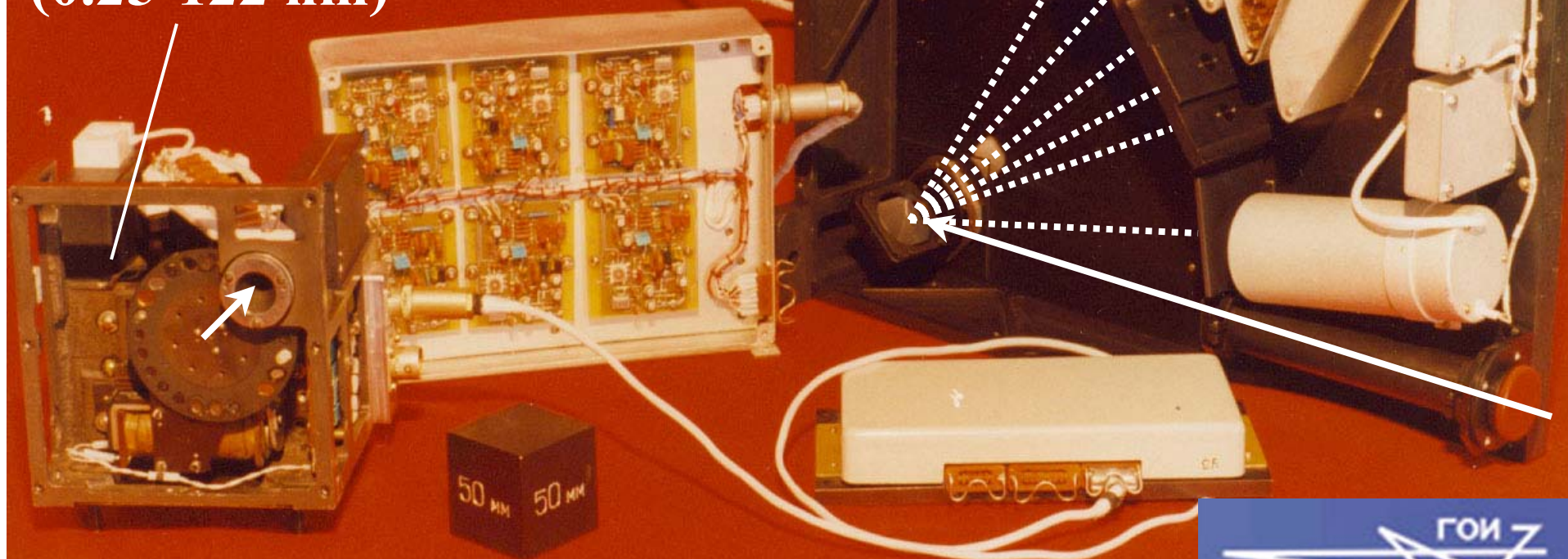
APPARATUS OF THE SPACE SOLAR PATROL

VUV spectrometer

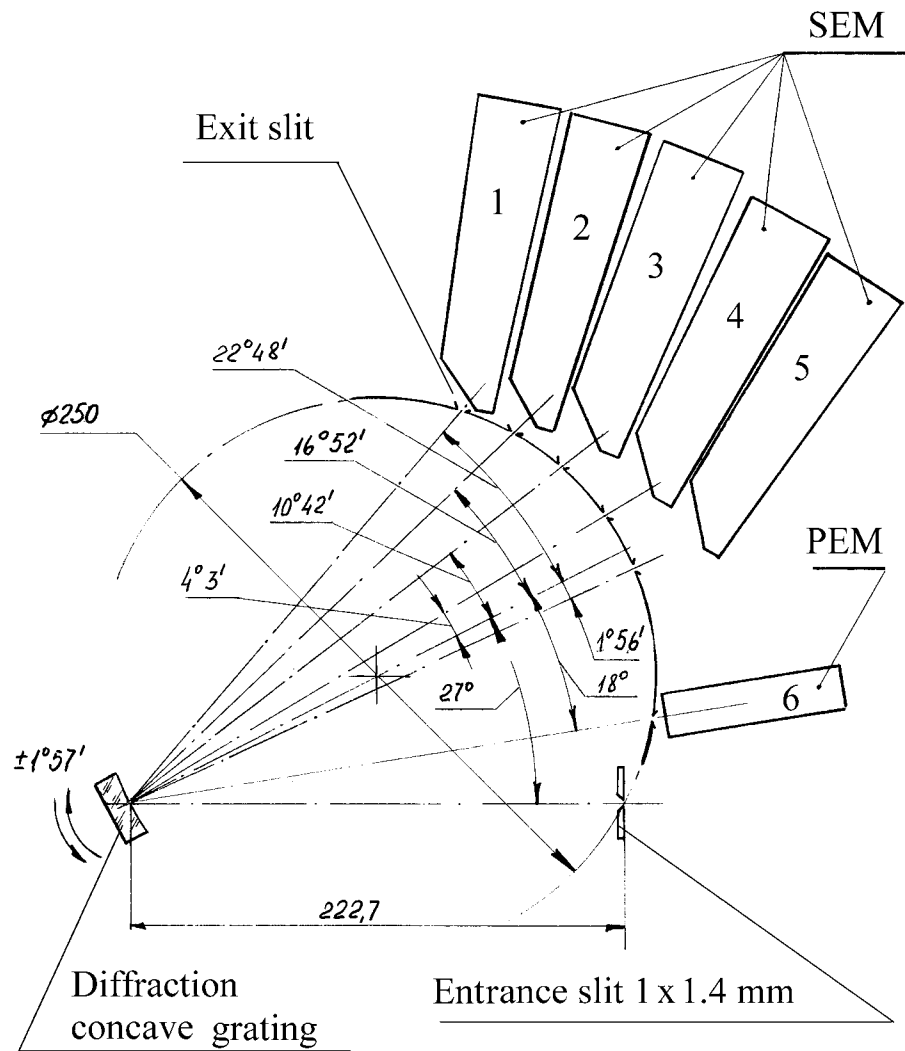
(16-122 nm)

Radiometer

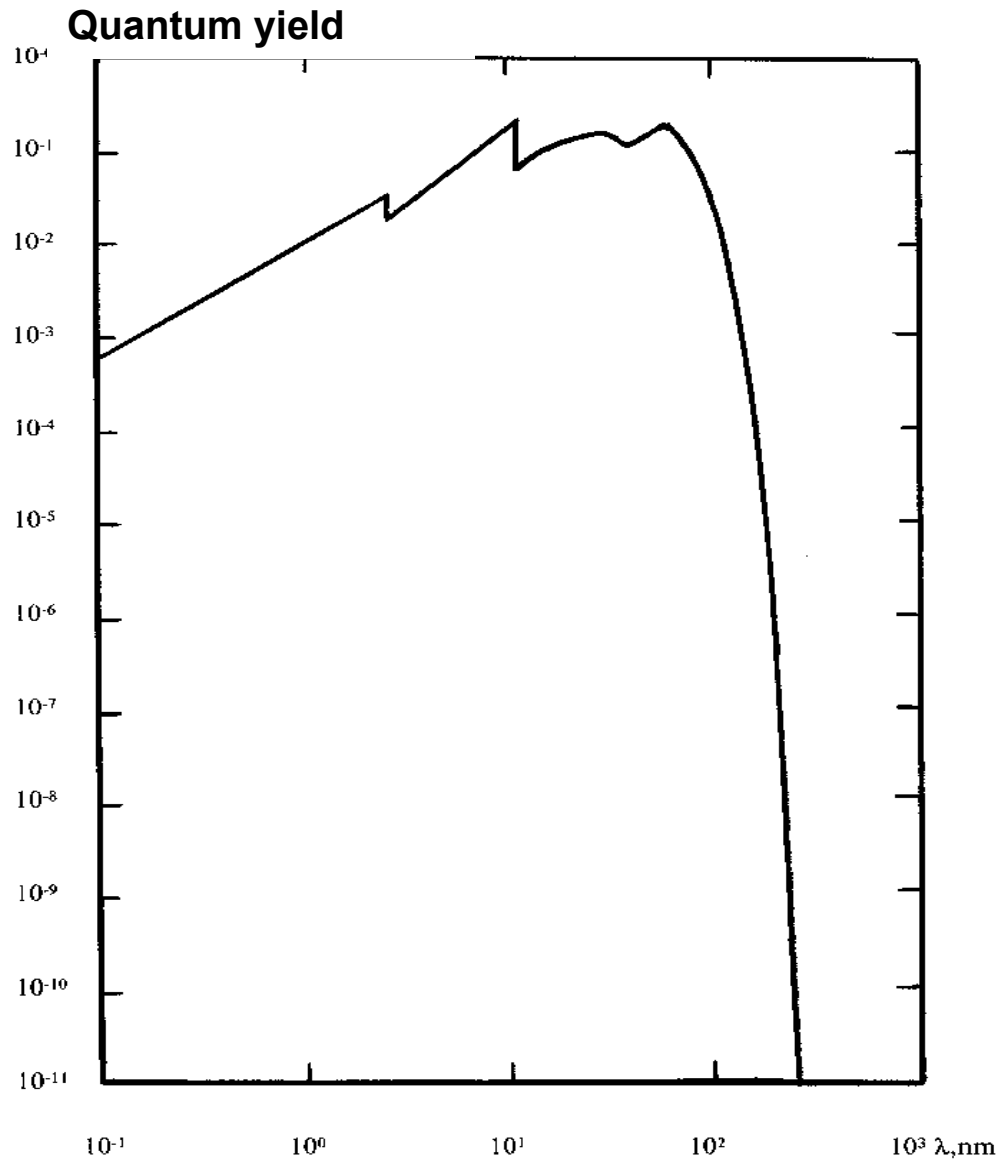
(0.25-122 nm)



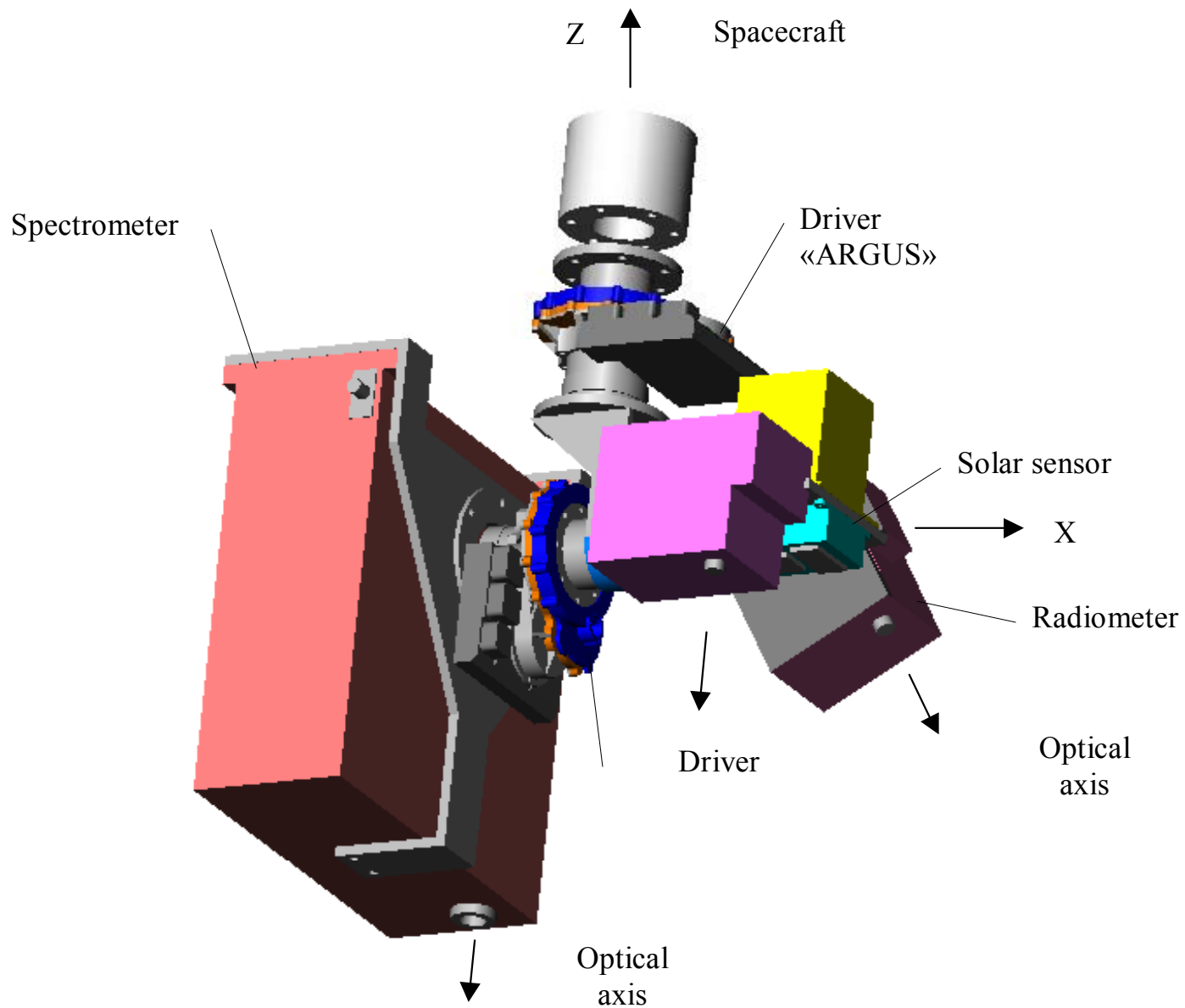
OPTICAL SCHEME OF THE VUV SPECTROMETER



Sun-blind SEM



Spectral distribution of the quantum yield of photoelectrons (pulse/quantum) for the BeO photocathode of the open secondary electron multiplier (SEM) produced by S.I. Vavilov SOI



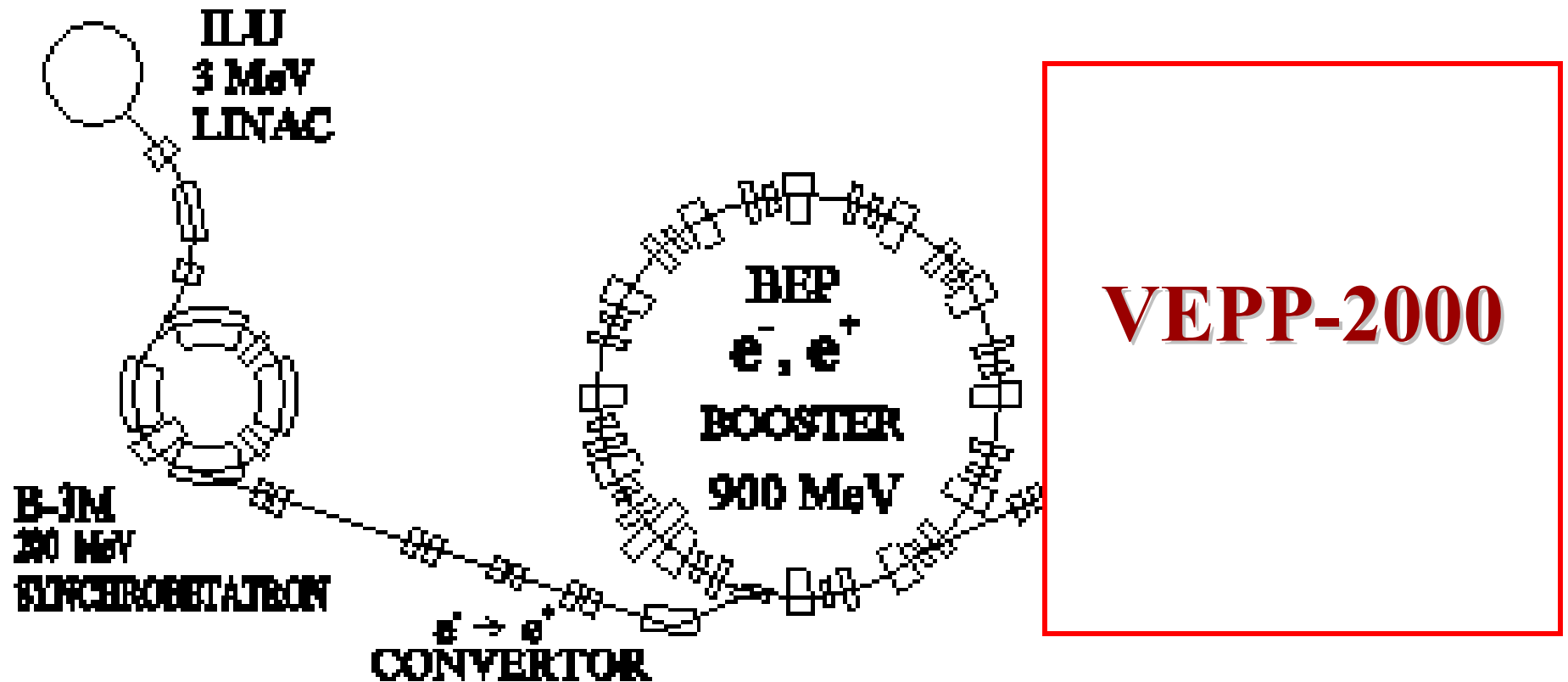
Scientific SSP instrumentation at the solar - oriented platform designed by **OAO "VNIITRANSMACH"** (variant).

A satellite, the Space Solar Patrol, is shown in orbit above Earth's atmosphere. The satellite has a complex structure with various instruments and solar panels. The background shows the curvature of the Earth and the blackness of space.

What kind of beamline is necessary for calibration the Space Solar Patrol? (*main performance requirements*)

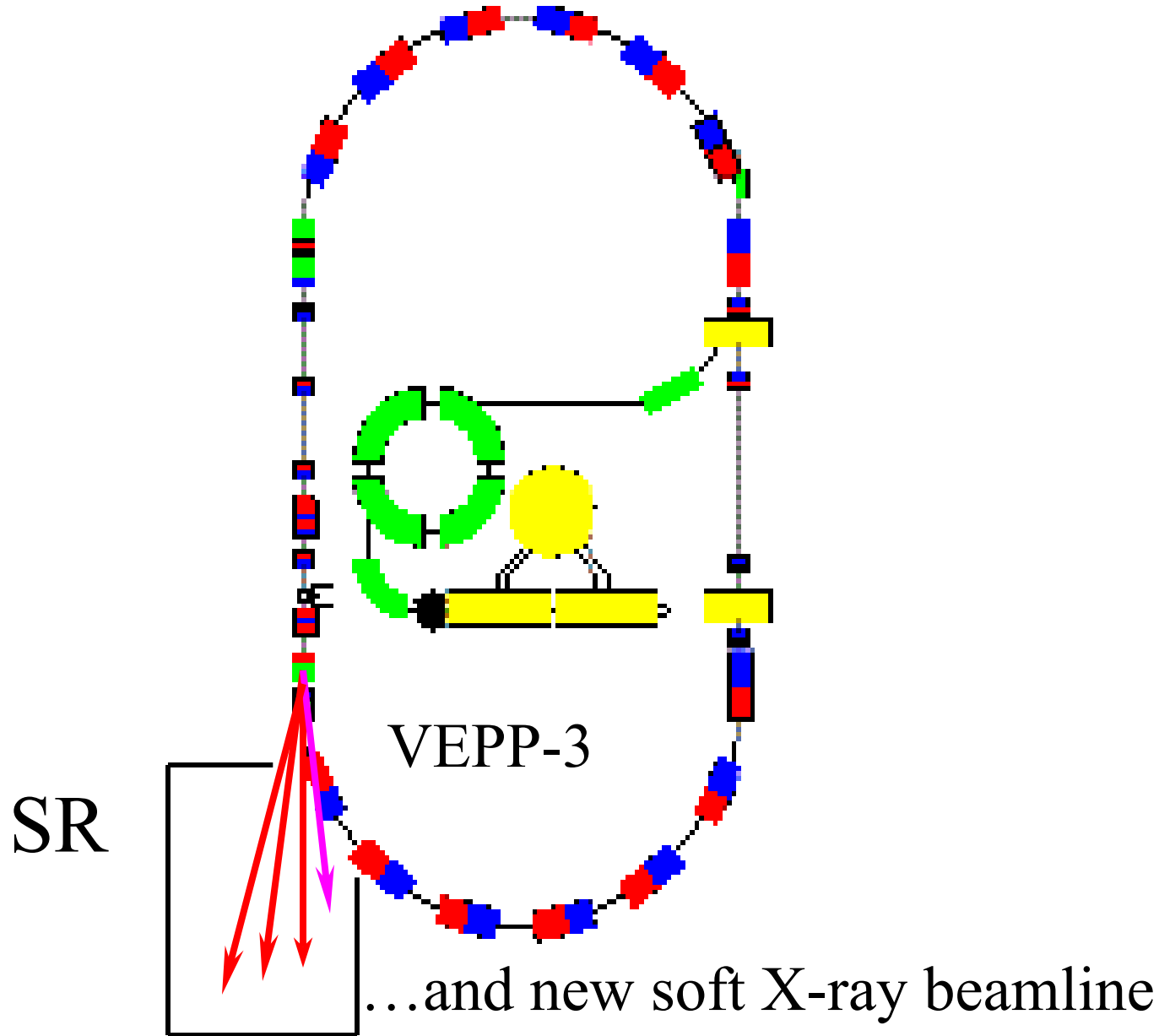
- **UHV compatible**
- **Without any vacuum-separating foils**
- **Differential pumping**
- **Fast closing system**
- **White SR beam**
- **Collimating system**
- **Monochromators 0.6-120 nm**
- **Mirrors**
- **Filters**
- ...

Soft X-ray & VUV metrology in the BINP before 2000
was based on the VEPP-2 storage ring

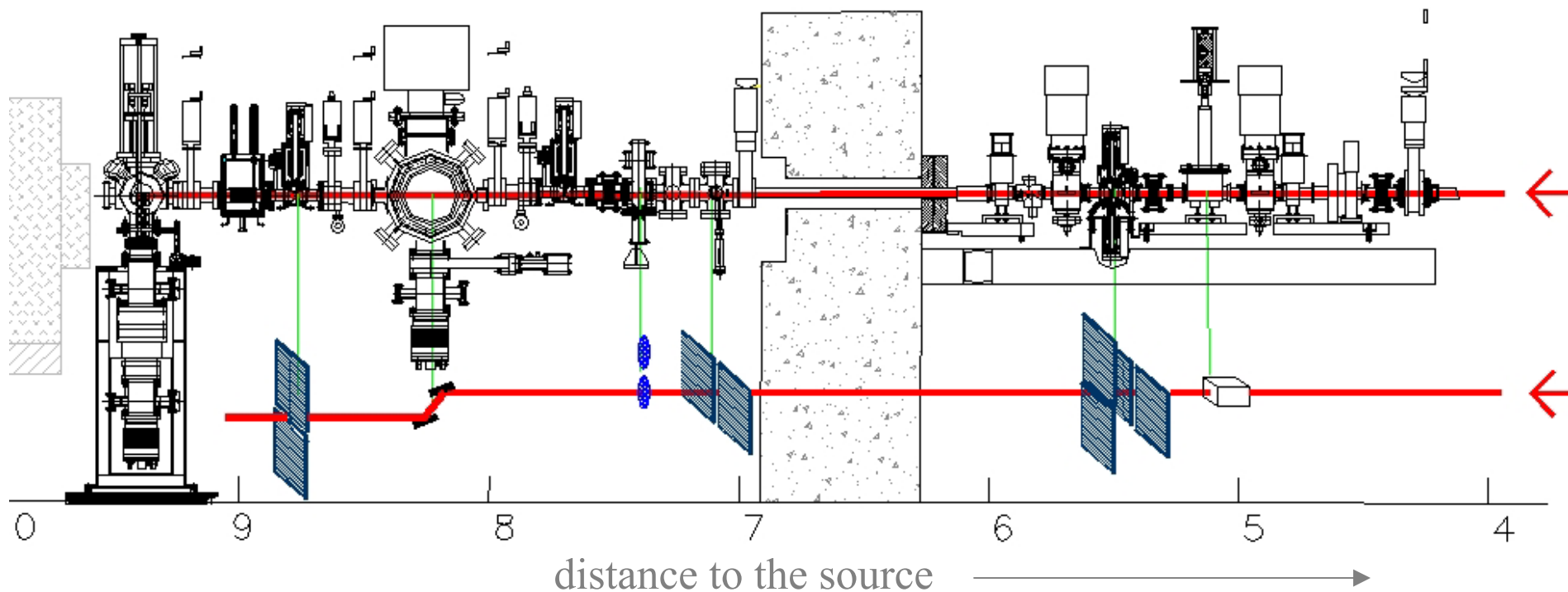


Now SR program on the VEPP-2000 is shutdown

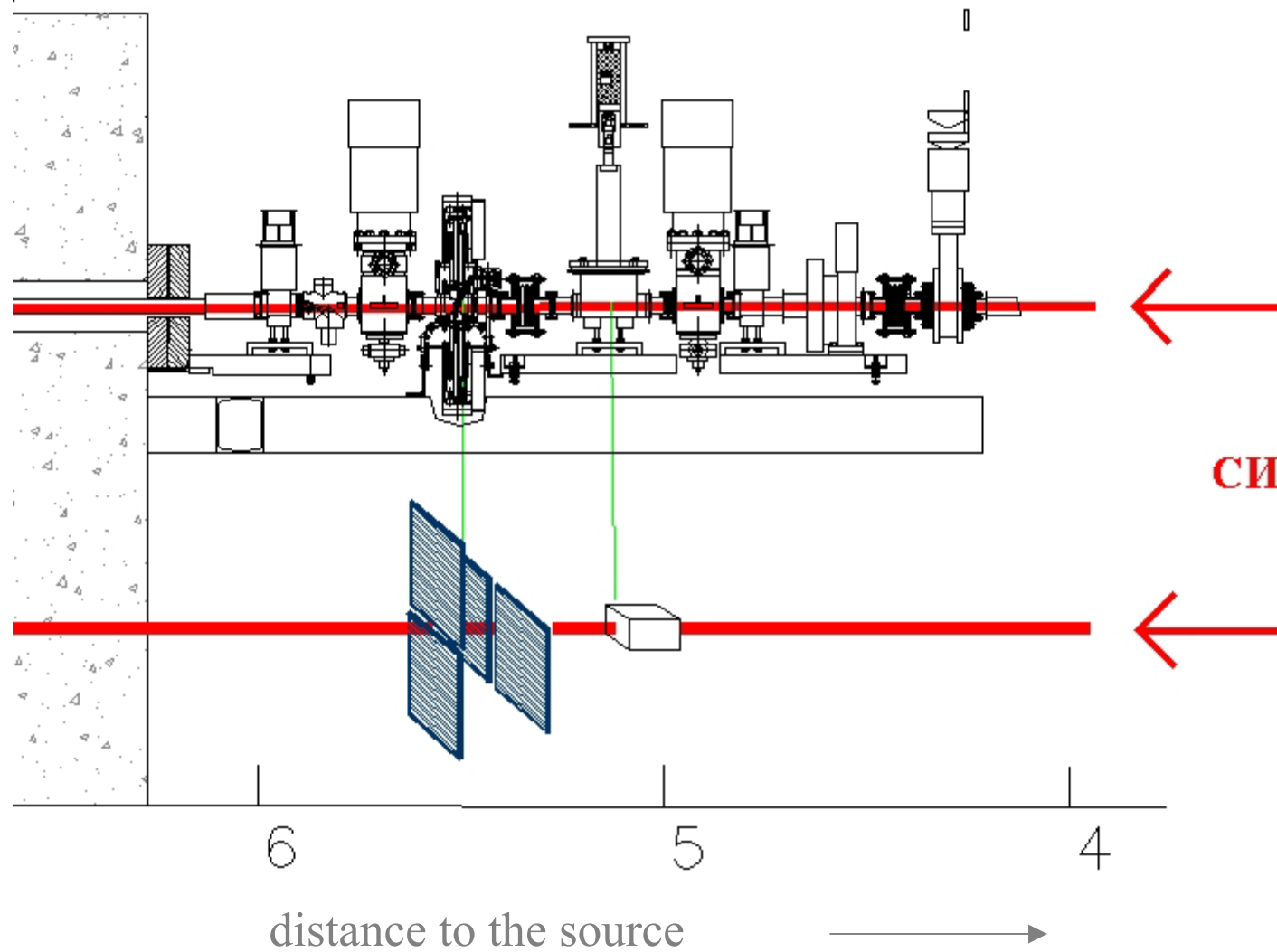
The 25-years-old SR experimental hall for hard X-ray ...



Layout of the metrology soft X-ray beamline on the VEPP-3 storage ring (0.2-15 nm)



Layout of the metrology beamline in hall of VEPP-3



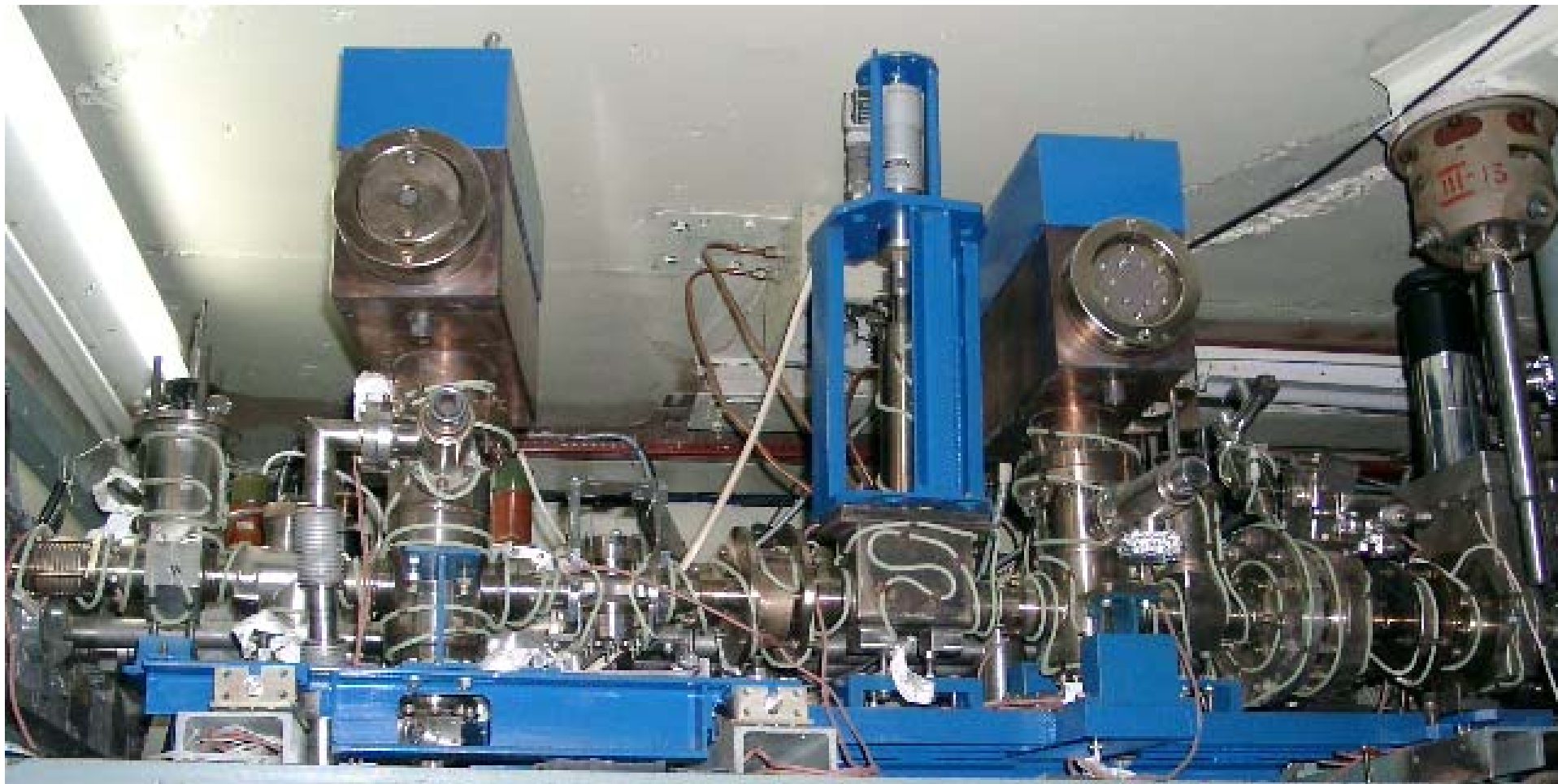
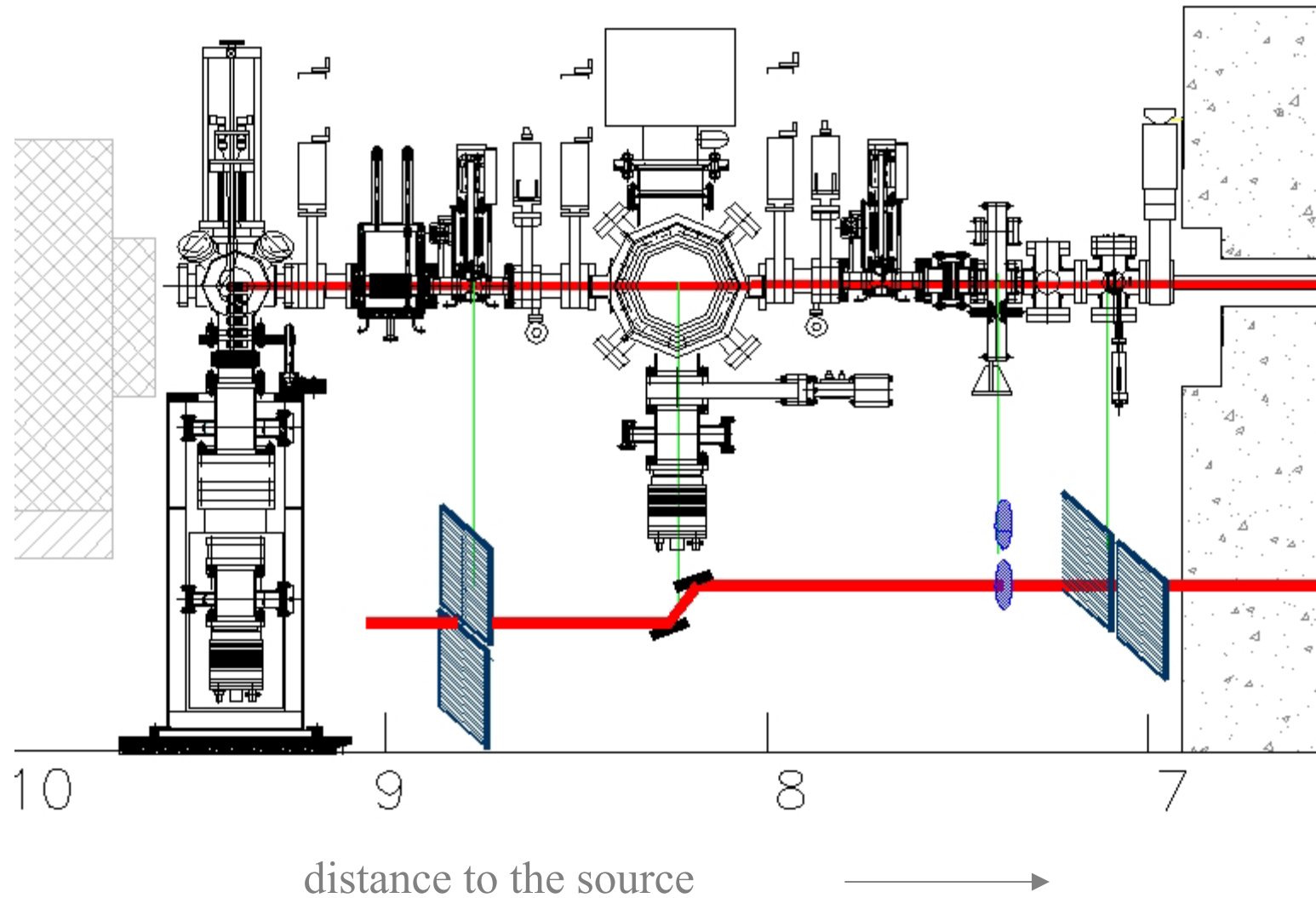


Photo of the metrology beamline in hall of VEPP-3

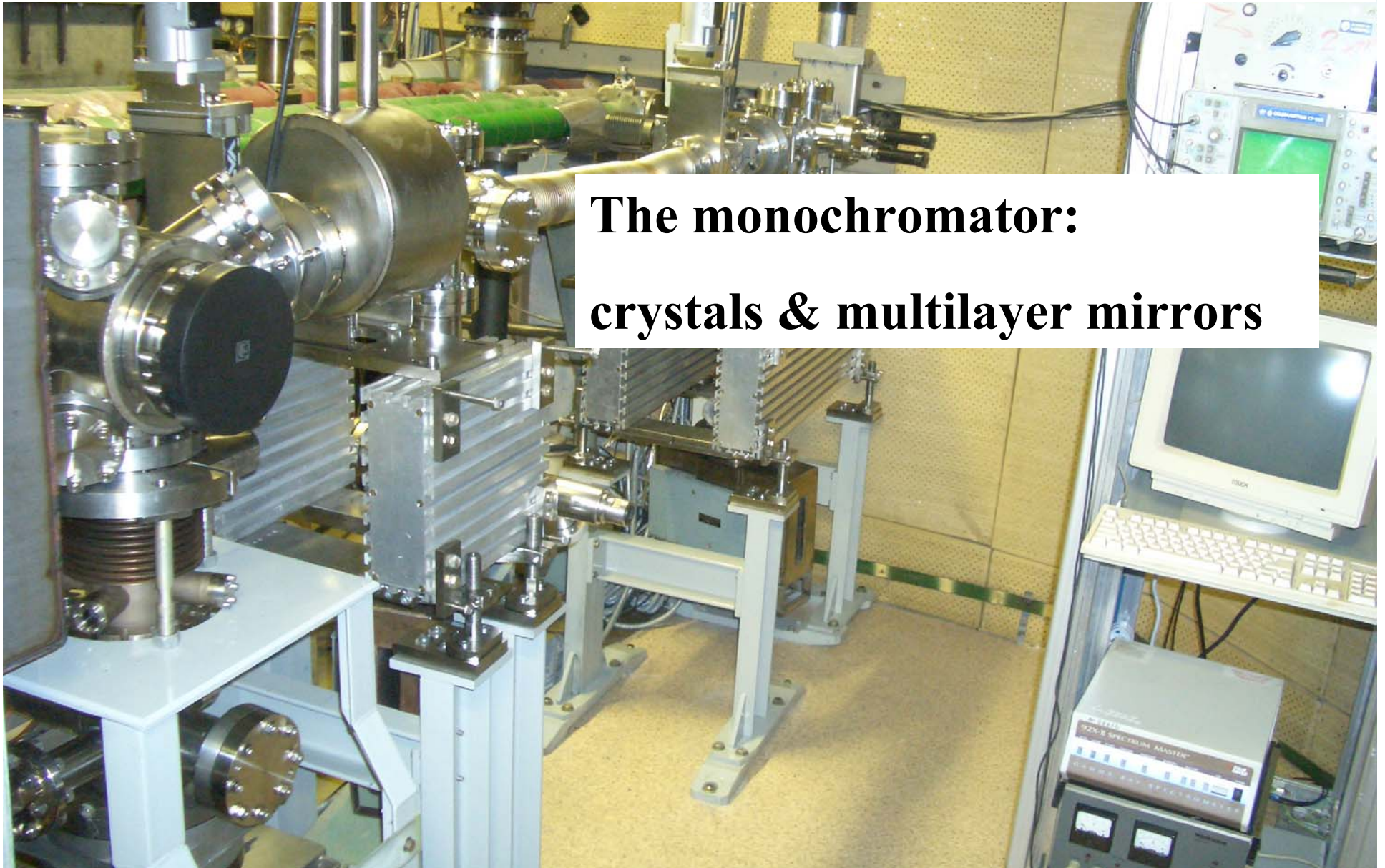
2003/11/10

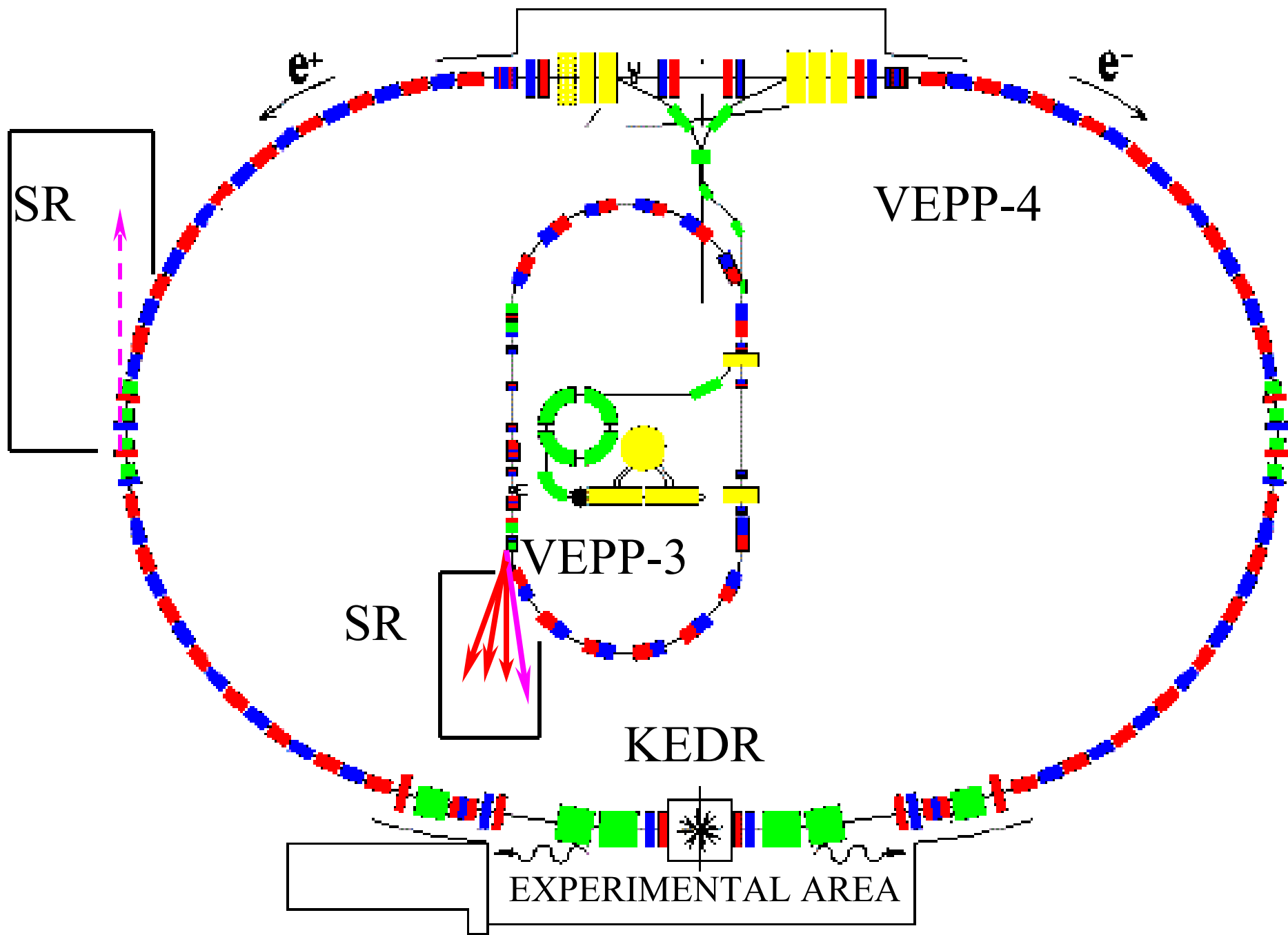
Layout of the metrology beamline in the experimental hall



**Photo of the metrology soft X-ray beamline (0.2-15 nm)
in the experimental hall**

**The monochromator:
crystals & multilayer mirrors**



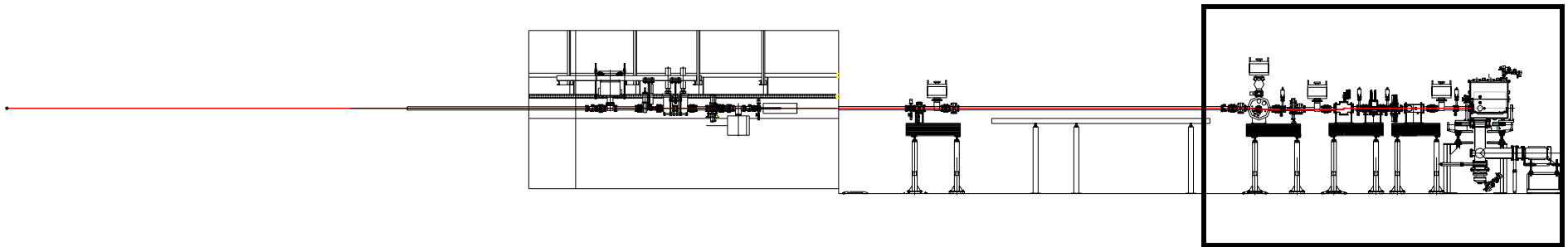


**Experimental hall for the working with SR from the
VEPP-4 storage ring**



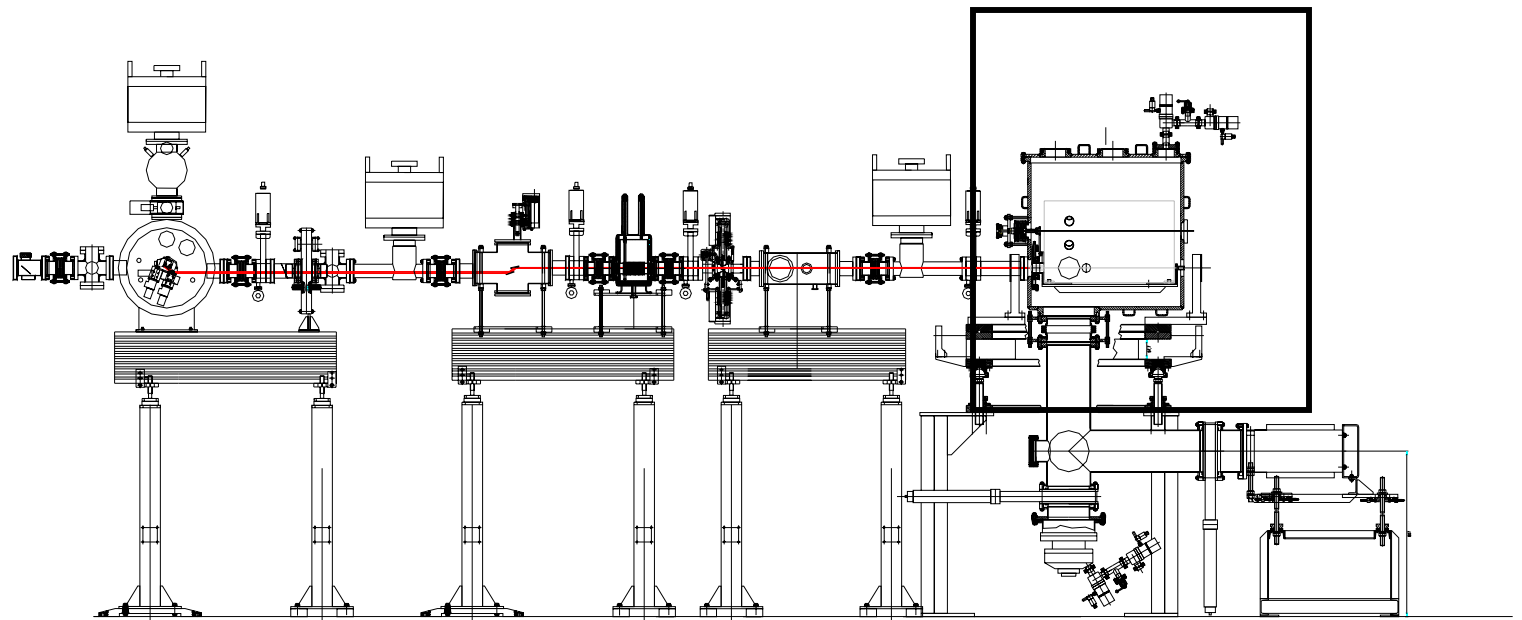
**Beamline №10 for the “Metrology” station (designing)
Users beam - 2006**

Layout of the “Metrology” soft X-ray and VUV beamline
(0.6-120 nm) on the VEPP-4 storage ring



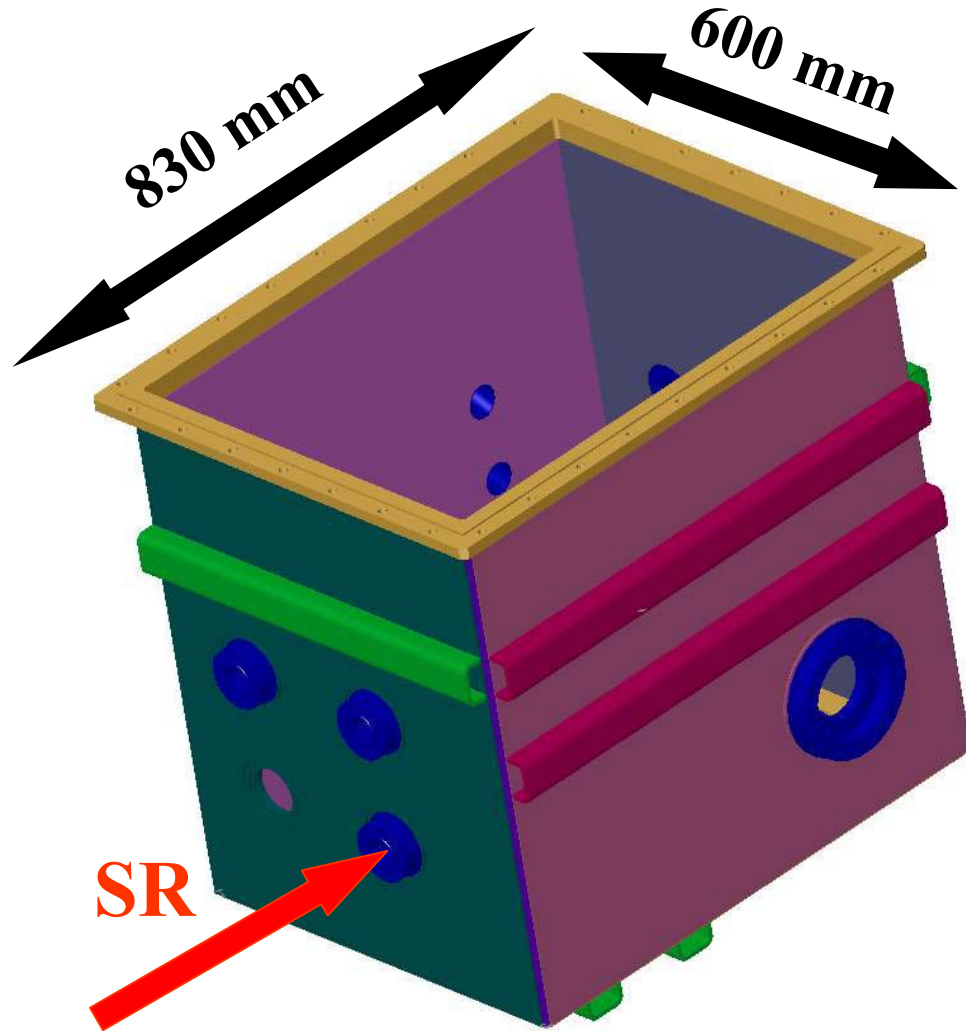
28 m to the source point

Layout of the beamline №10 in the experimental hall

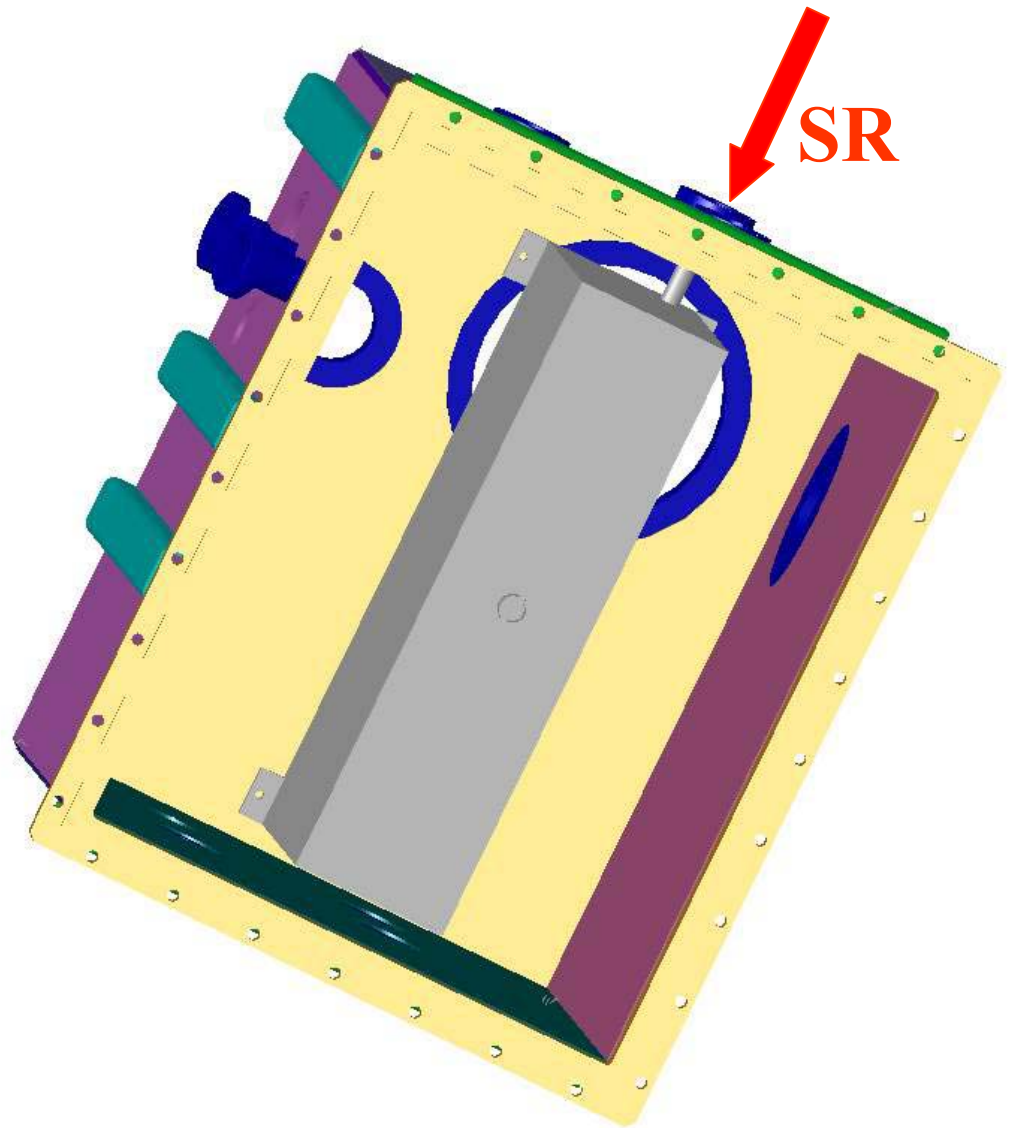


28 m to the source point

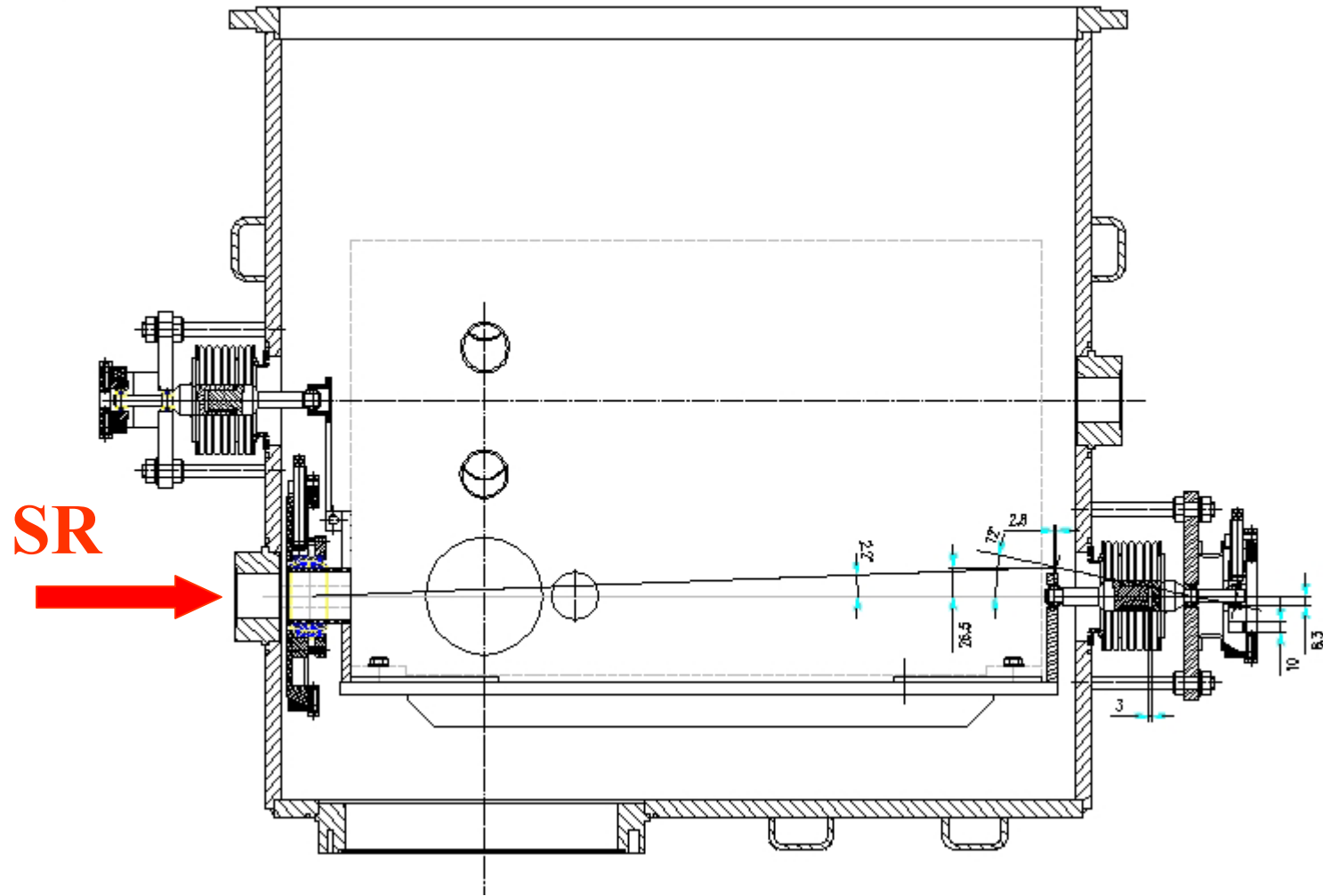
Experimental chamber for the calibration of the Space solar patrol

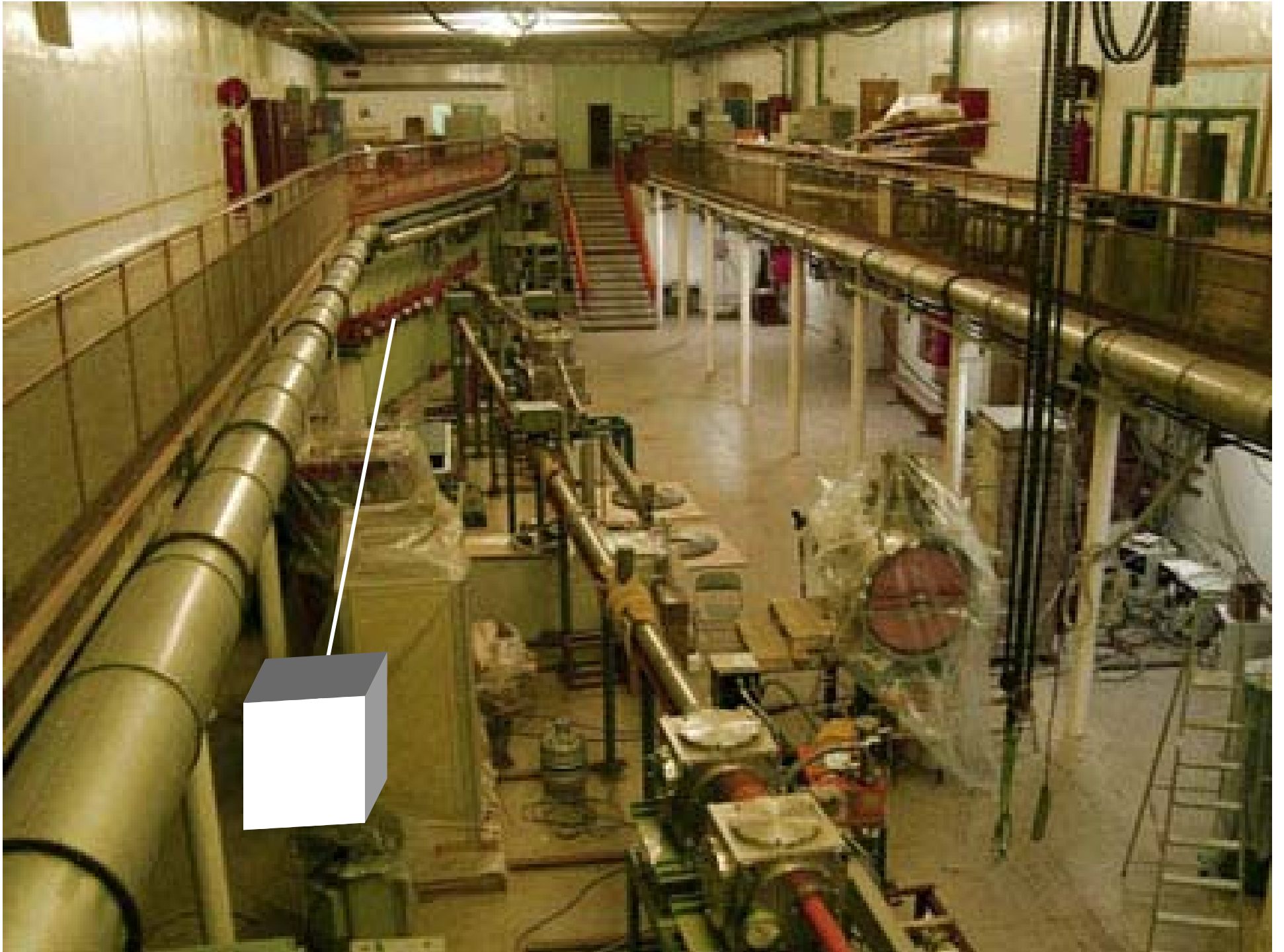


Position of the X-ray spectrometer in the experimental chamber



Position of the X-ray spectrometer in the experimental chamber with 4-degree-freedom adjustable system

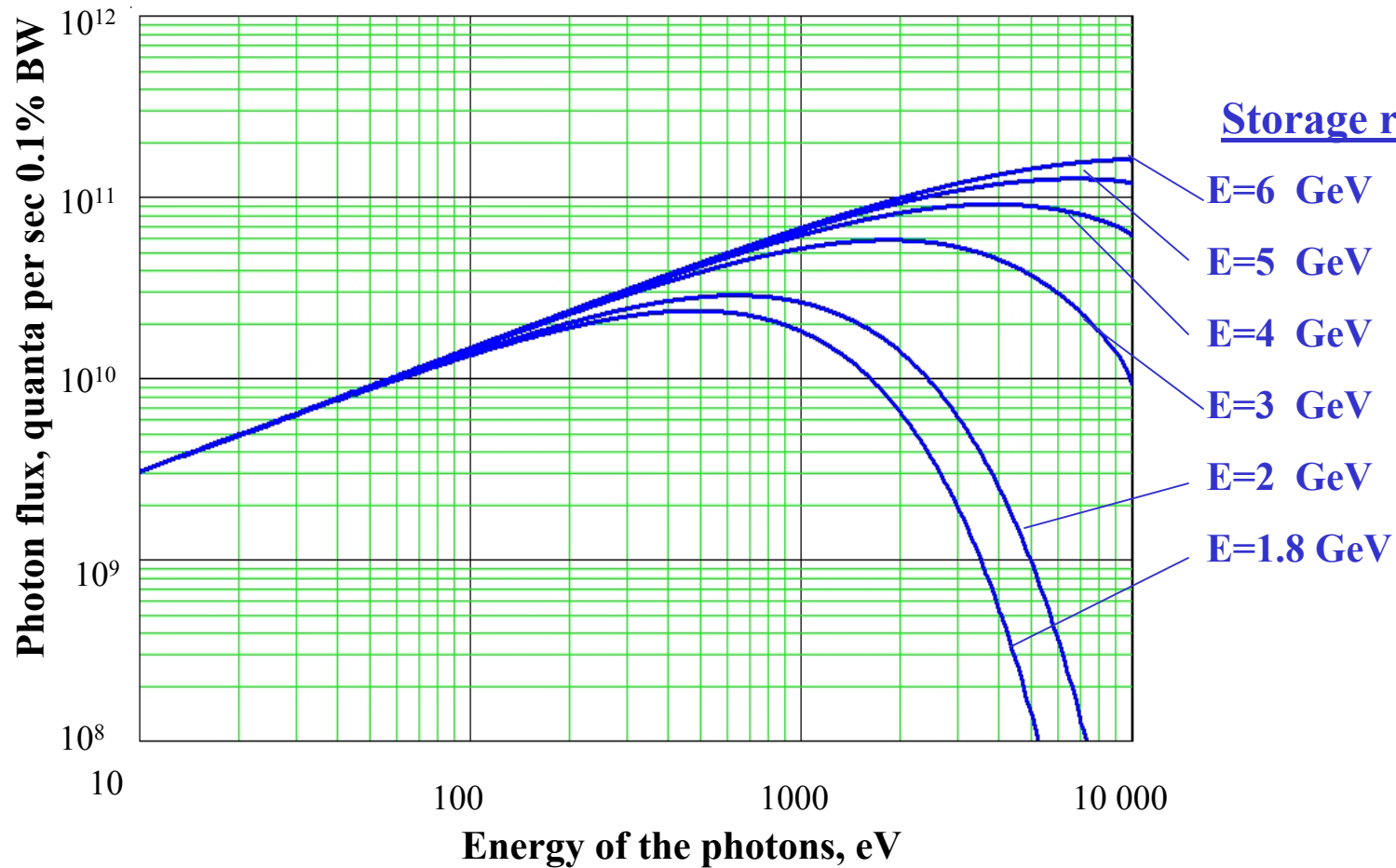




Photon flux from the «Methrology» station (BL№10-4) for different energy of electrons in the VEPP-4 storage ring.

Beamline parameters:

aperture - 5X5 mm, distance to the source - 30 m bandwidth $\Delta E/E=10^{-3}$

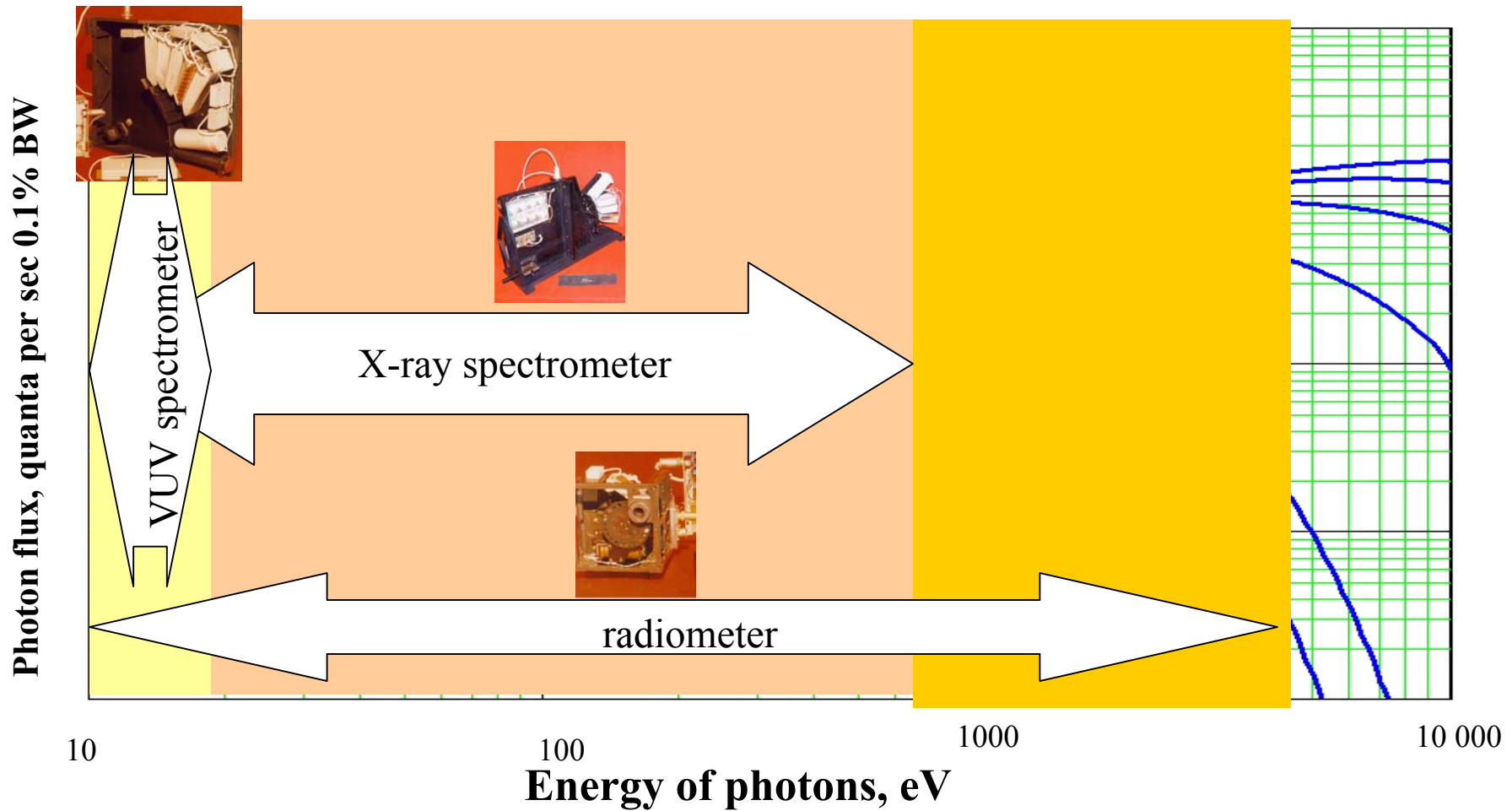


Storage ring parameters:

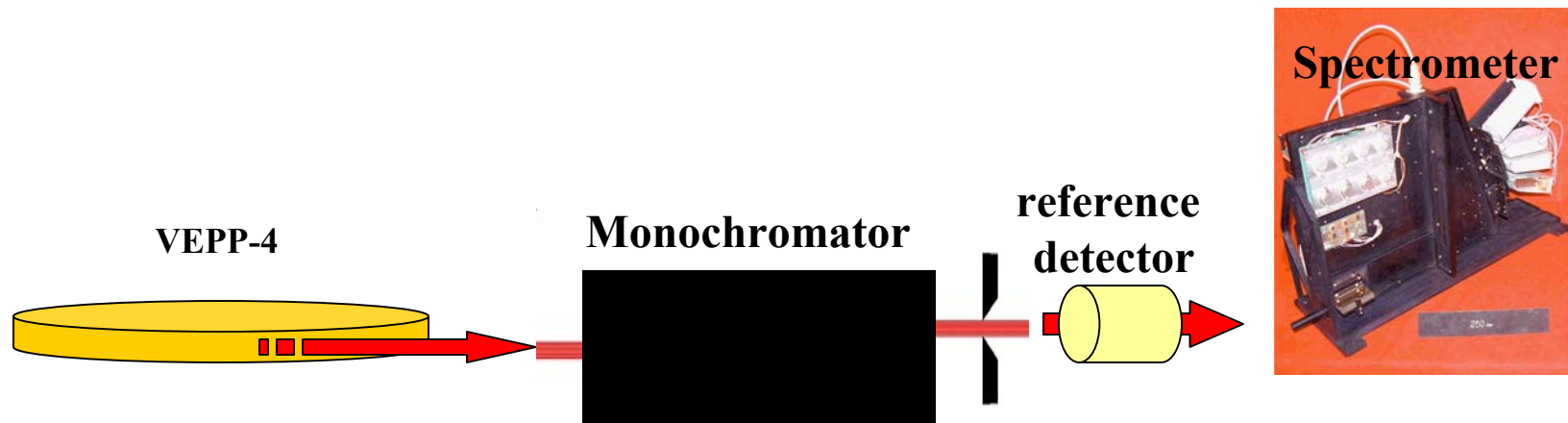
Current:
I=10 mA,

Energy of electrons
E=1.8 ... 6 GeV

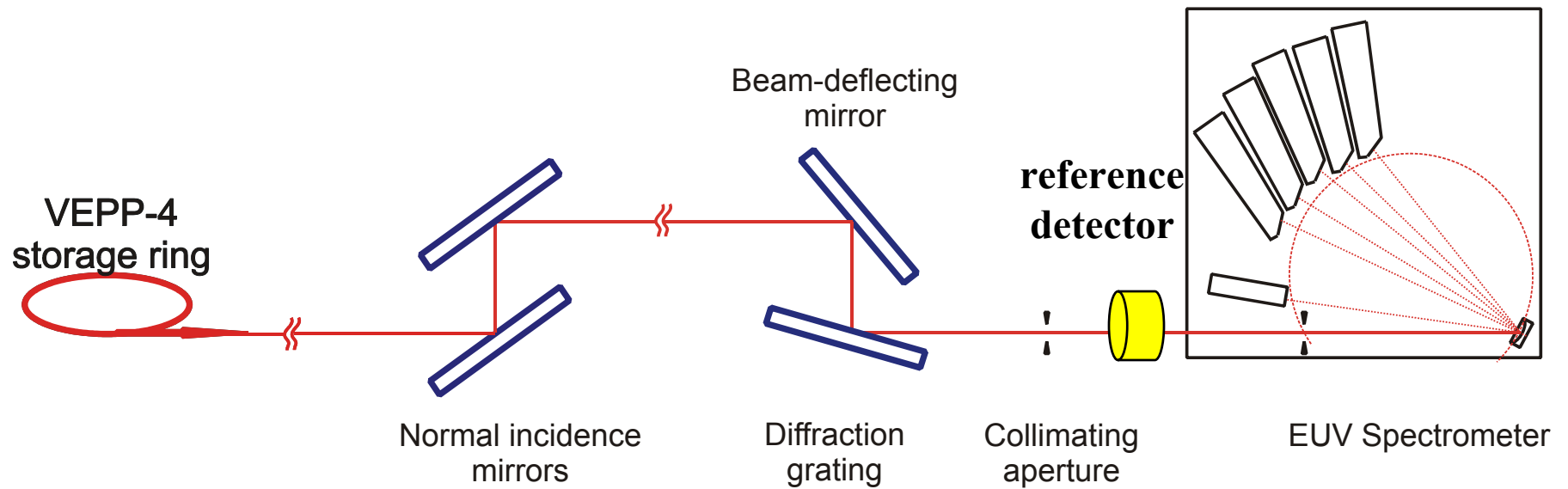
Spectral range of the apparatus of the Space Solar Patrol and photon flux from the VEPP-4 storage ring



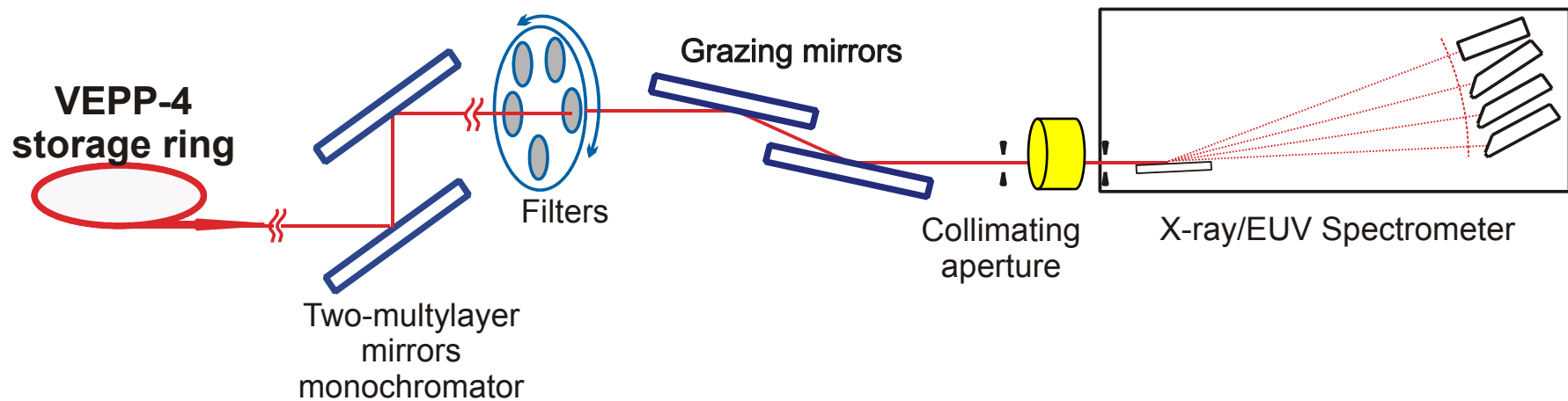
Calibration of the spectrometer using the reference absolute detector



Optical schemes of the detector – based calibration of EUV spectrometer

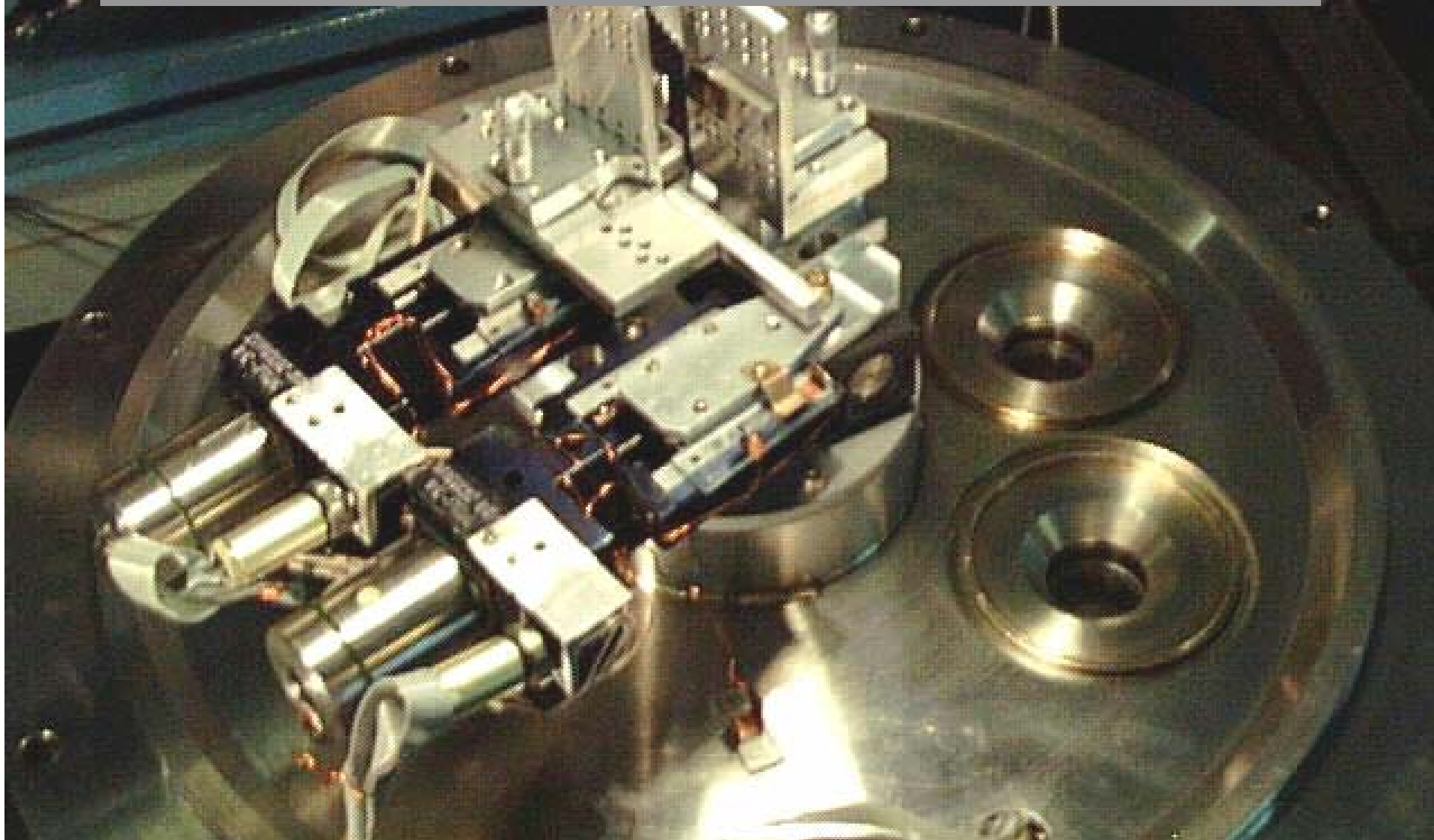


Calibration of EUV-soft X-ray spectrometer in the 6-122 nm spectral range



Two-multilayer-mirrors monochromator of the
“Metrology” station

Spectral range - 100 eV-2000 eV

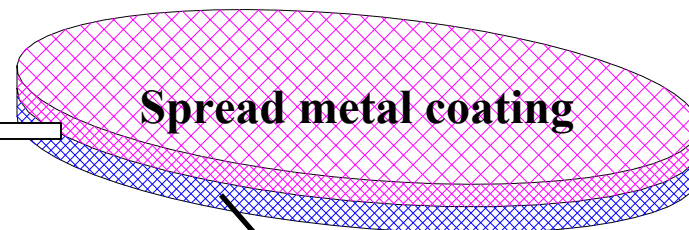


Whence to take the reference detector?

- To buy is
- To calibrate it on one's own
- ...or to use both ways

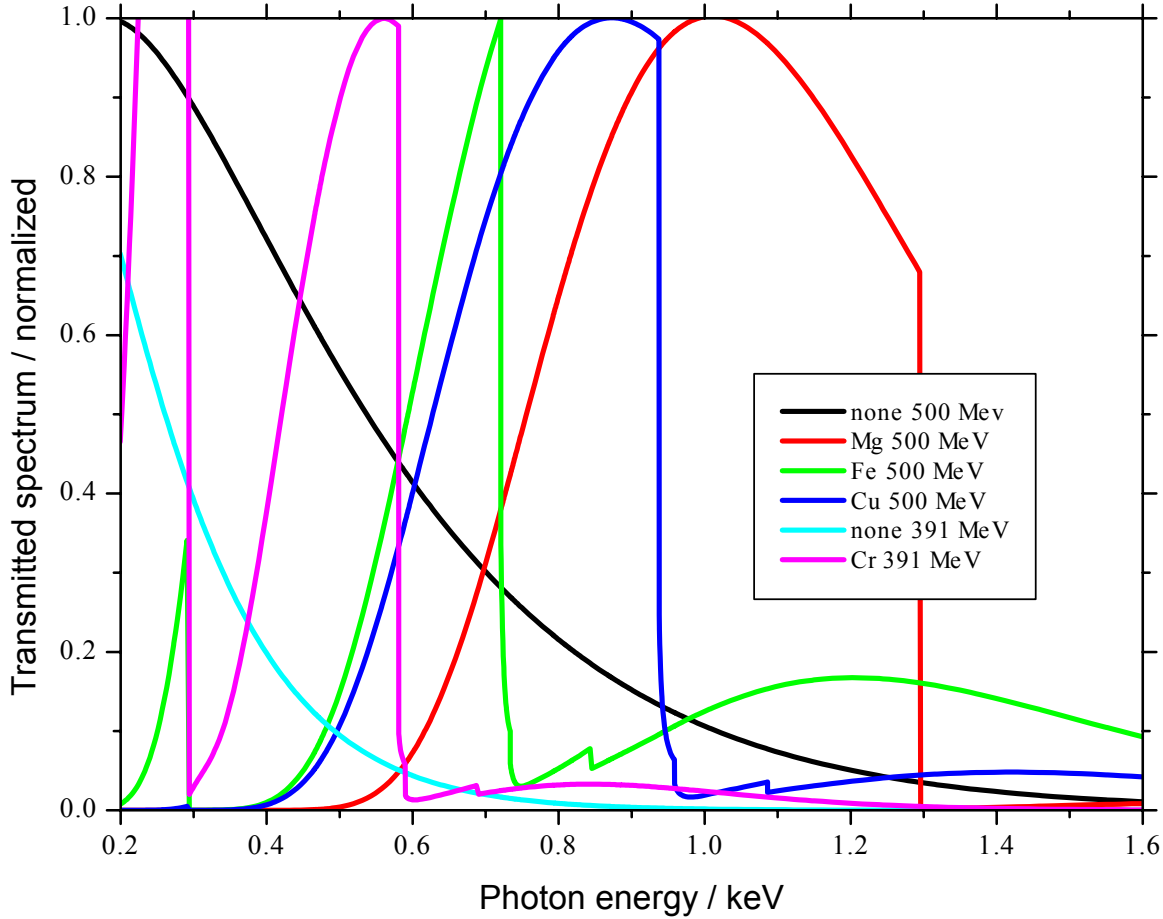


**SPPD-11 - candidates for the reference
X-ray detectors and absorbed filters**
calibrated in the BINP with collaboration with VNIIEF
spectral range of calibration – 0.06-10 nm,
average inaccuracy is about 5-7%
(ISTC project #438)



substrate -polyparaxylylene (CH)_n

The transmitted spectrum of SR behind different filters.



The signal of the irradiated detector is associated with the calculated SR spectrum as follows:

$$\int_0^{\infty} \underbrace{\psi(E)} \cdot \underbrace{\exp(-\mu_i(E) \cdot h_i)} \cdot \underbrace{s(E)} dE = I_i$$

$\psi(E)$ – the spectral radiant power of the SR, W/keV;

$\mu_i(E)$ – the X-ray mass absorption coefficient of the i -index filter, cm²/g;

h_i – the mass thickness of the i -index filter, g/cm²;

$s(E)$ – the spectral responsivity of the detector, A/W;

I_i – the detector current during the irradiation behind the i -index filter, A.

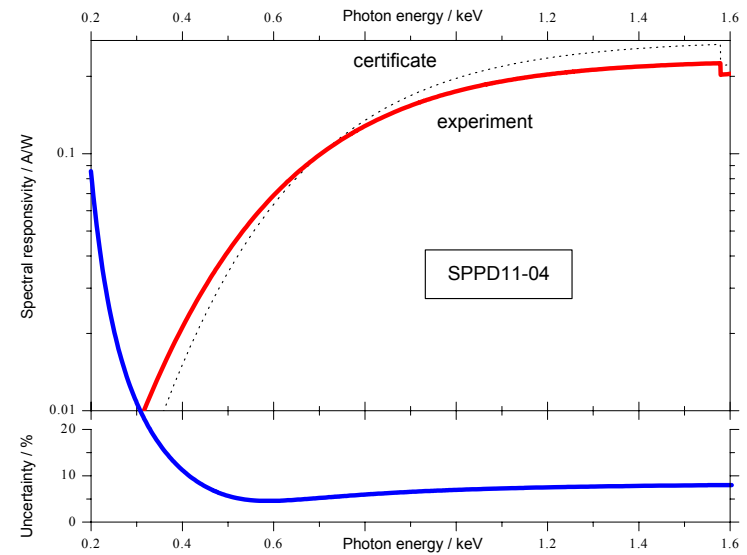
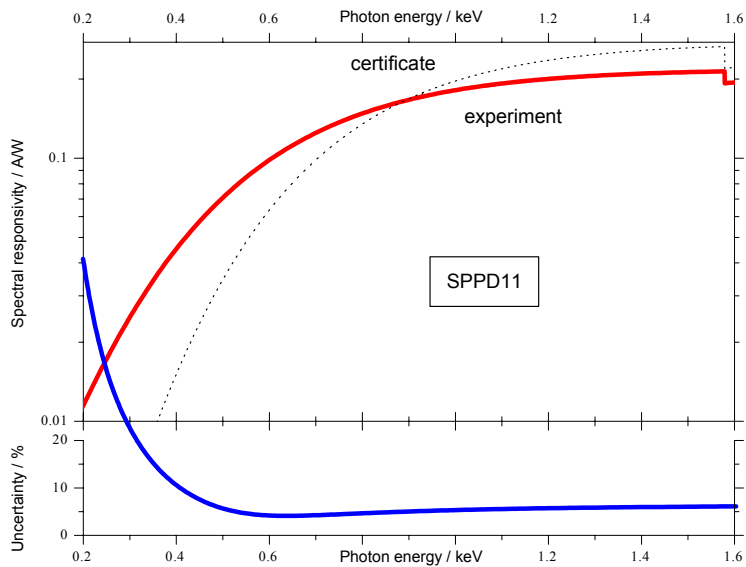
Solution of such a system of integral equations is extremely unstable if it has been calculated without *a priori* information. In our case, such information consisted in the parametrical form of the spectral responsivity defined as:

$$s(E) = k_{cc} \cdot \frac{e}{\omega} \cdot \exp(-\mu_c(E)h_c - \mu_d(E)h_d)$$

- k_{cc} – the charge carriers' collection coefficient in the semiconductor;
- e – the electron charge, equal to 1.6×10^{-19} C;
- ω – the energy of pair creation in Si, which is assumed to be equal to 3.66 eV/pair [3];
- h_c – the mass thickness of the aluminum contact deposited on the detector surface, g/cm²;
- h_d – the mass thickness of the dead layer, g/cm².

Detector parameters restored from the measurements

| Parameter | SPPD11 | | SPPD11-04 | |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|
| | Certificate | Experiment | Certificate | Experiment |
| k_{cc} | 1 | 0.79 ± 0.05 | 1 | 0.84 ± 0.07 |
| h_d (mg/cm ²) | 0.05 ± 0.02 | 0.02 ± 0.01 | 0.05 ± 0.02 | 0.04 ± 0.01 |



Particularities of the SR calibration

A satellite in space, likely the International Space Station, is shown with its solar panels and various instruments. The satellite is positioned in the center of the frame, with the Earth's horizon visible in the background. The solar panels are extended horizontally, and the main body of the satellite is oriented vertically. The background is a dark, clear sky, suggesting a high-altitude or orbital environment.

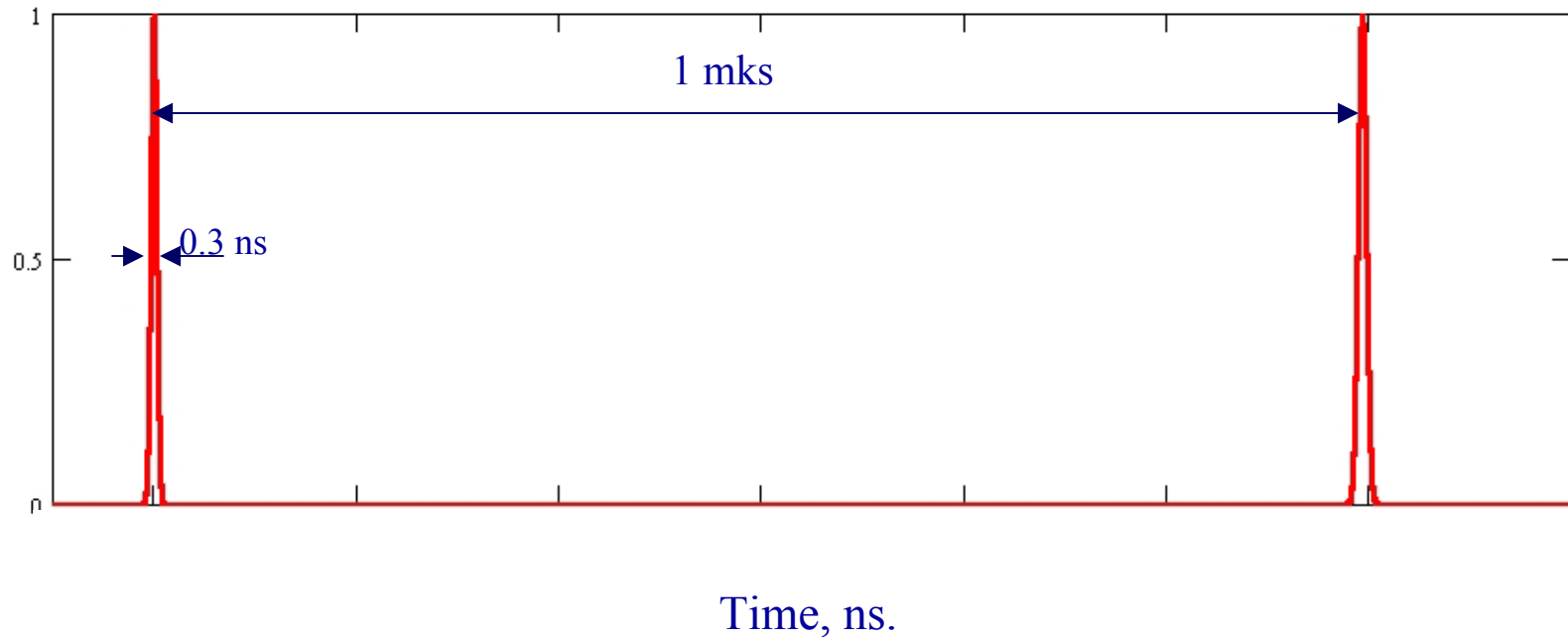
- Time modulation of the SR beam
- Phase-space volume
- SR polarisation

Particularities of the SR calibration

A satellite in space, likely the International Space Station, with solar panels and various instruments. The satellite is positioned in the center of the frame, with its solar panels extending outwards. The background shows the Earth's horizon and the blackness of space.

- **Time modulation of the SR beam**
- Phase-space volume
- SR polarisation

The time scale of flashes of SR.

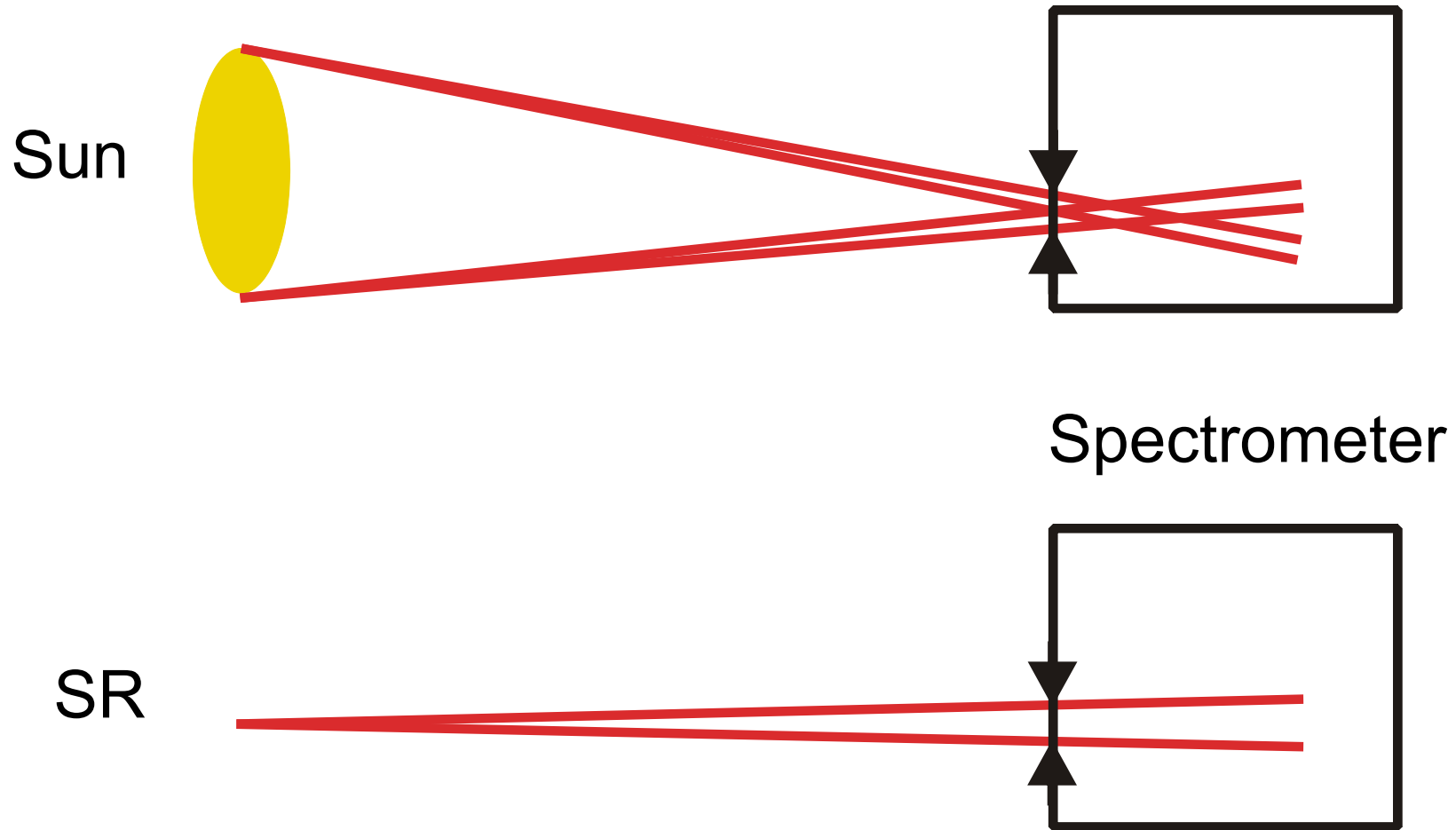


Particularities of the SR calibration

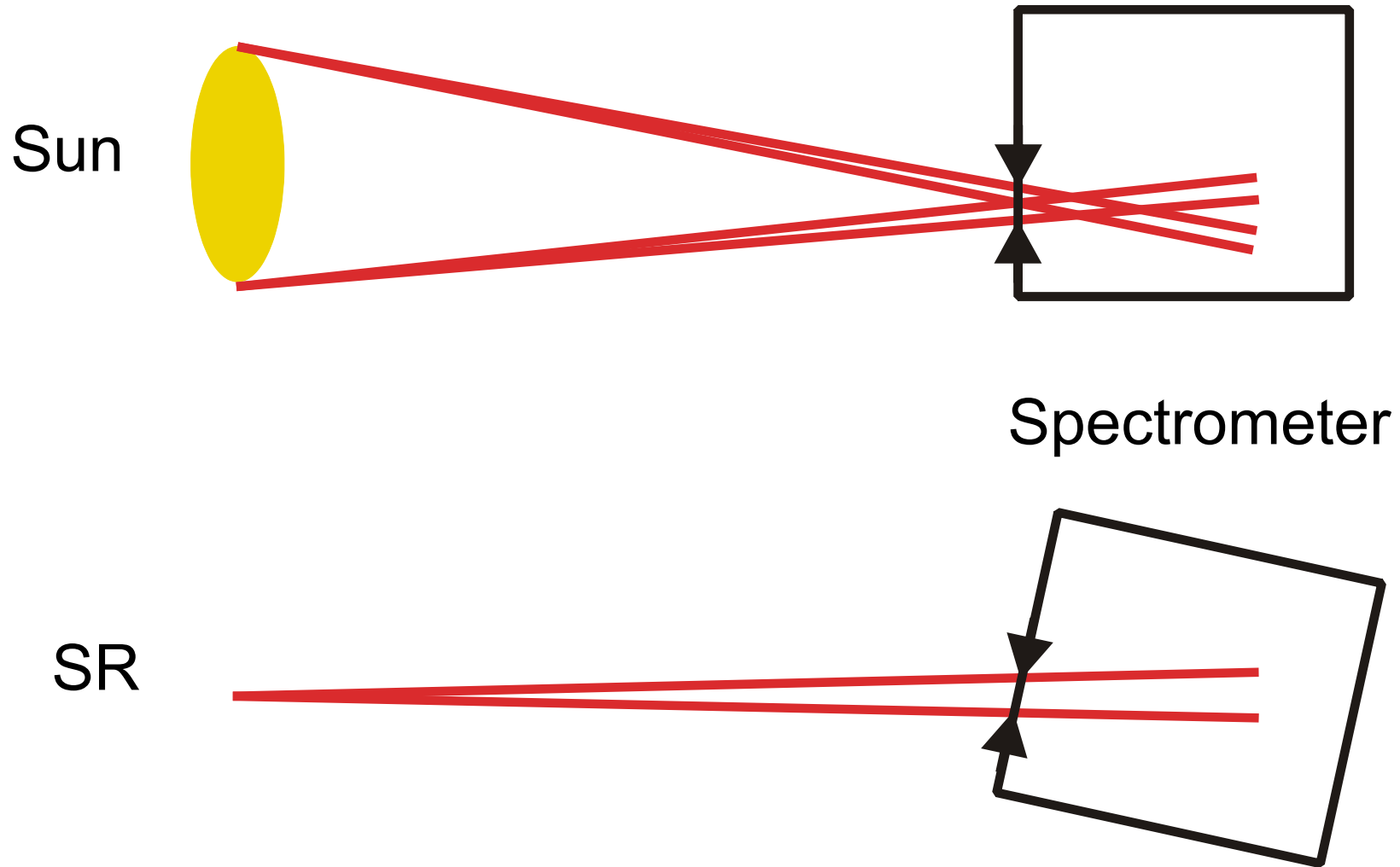
A satellite in space, likely the International Space Station, is shown against a black background. The satellite has a complex structure with multiple solar panel arrays extending from a central body. The Earth's horizon is visible at the bottom of the frame, showing a thin blue line of the atmosphere. The satellite is oriented vertically, with its main structure pointing towards the top of the image.

- Time modulation of the SR beam
- **Phase-space volume**
- SR polarisation

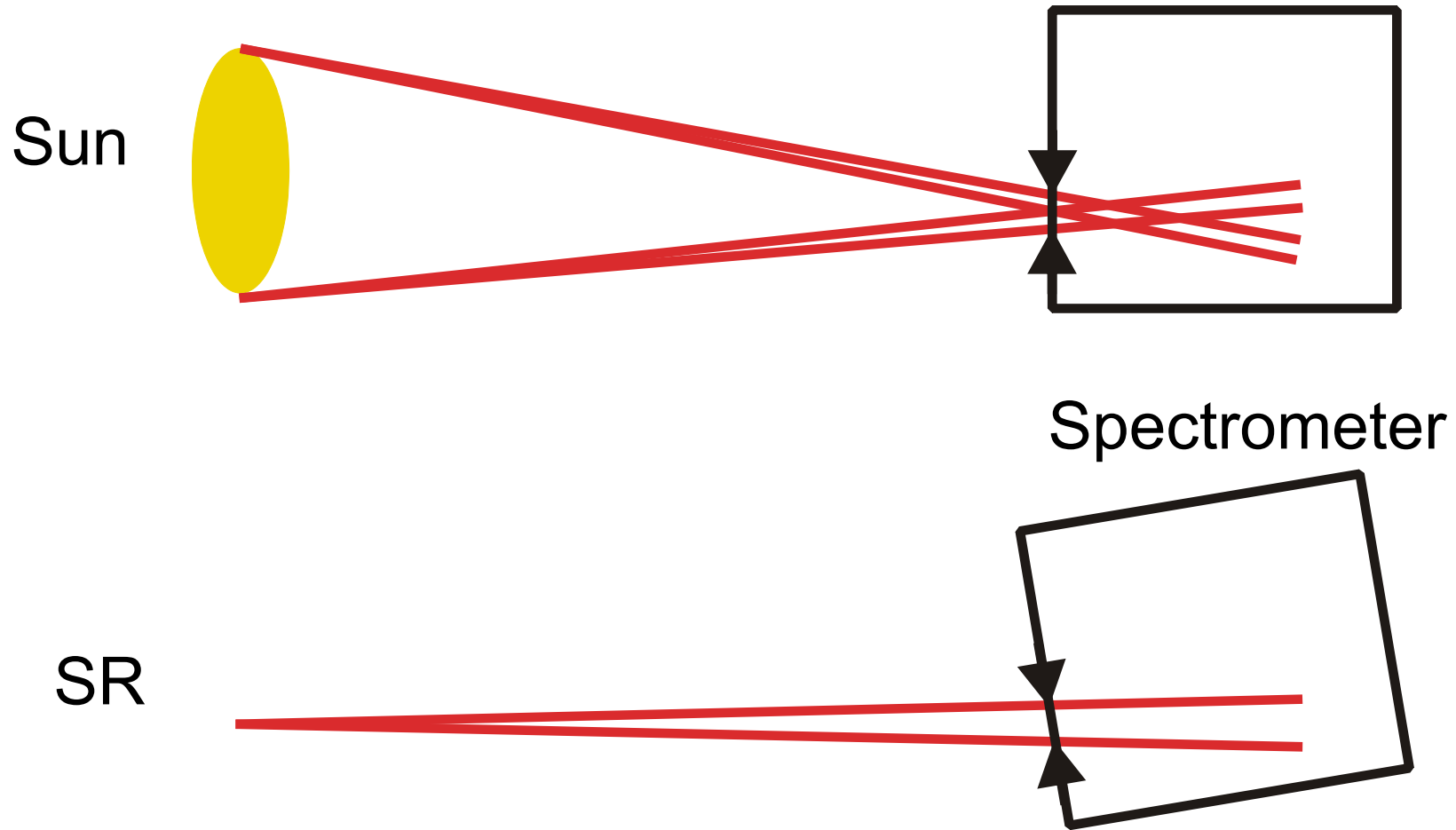
Phase-space volume



Phase-space volume

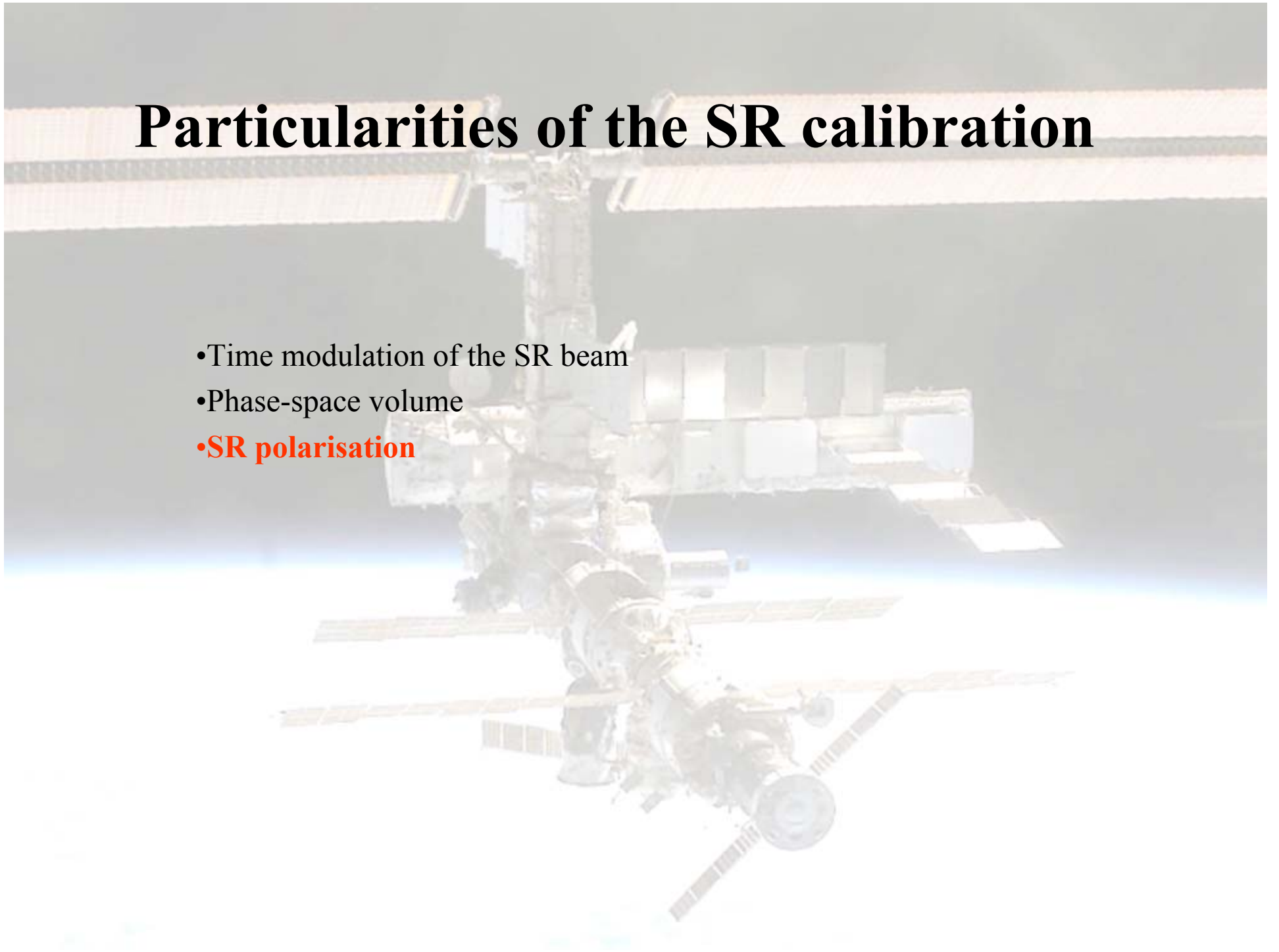


Phase-space volume



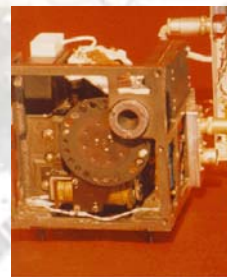
Particularities of the SR calibration

- Time modulation of the SR beam
- Phase-space volume
- **SR polarisation**



Conclusion:

It is offered the absolute calibration procedures at the synchrotron radiation sources in the spectral range from 0.25 up to 122 nm (5000 - 10 eV) for the Space Solar Patrol (SSP) instrumentation. Thus, the methods of reference detectors and selective absorbing filters are accepted as a basis. BINP at cooperation with SOI has sufficient opportunities for calibration SSP in this spectral range with accuracy about 10%.

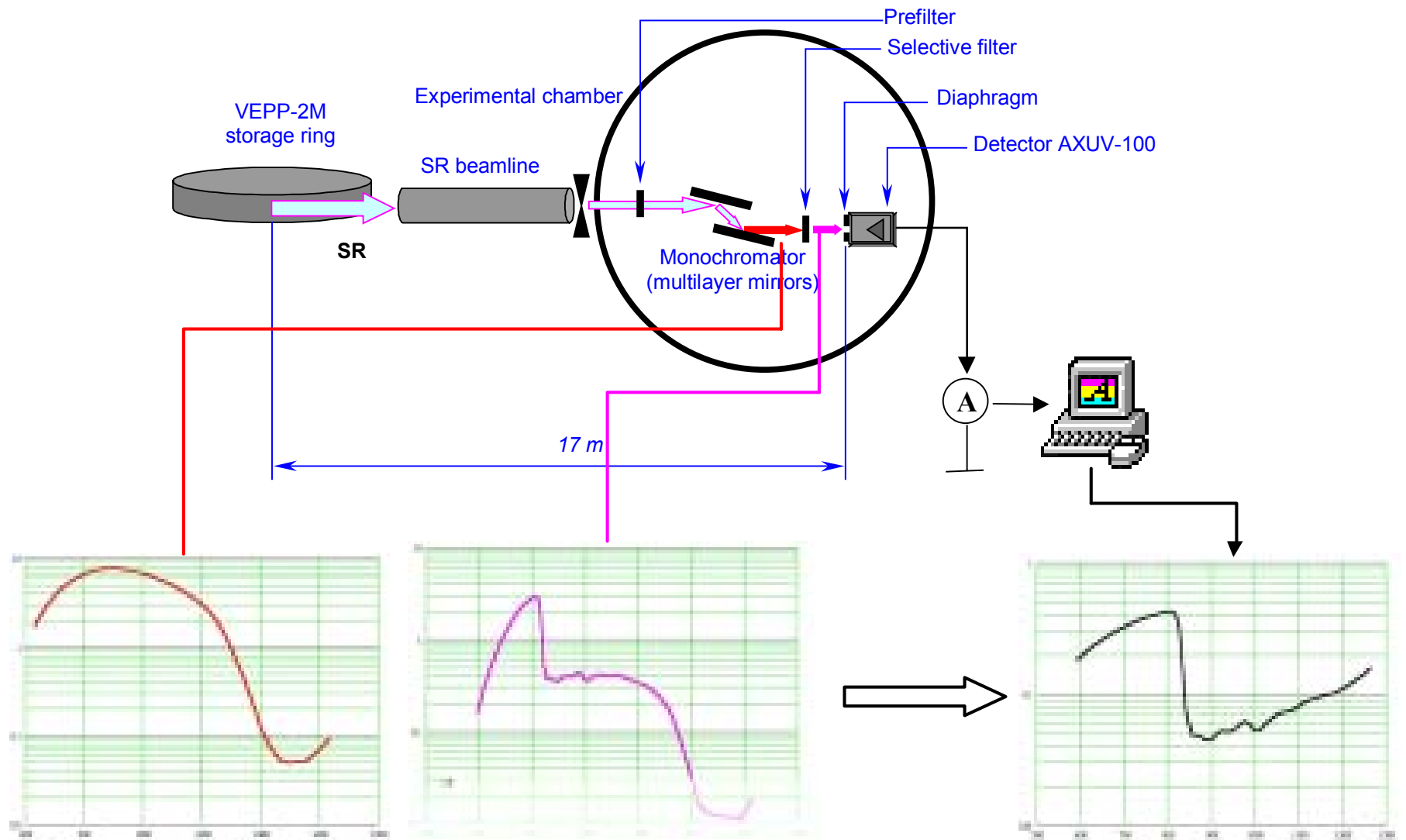


Acknowledgments

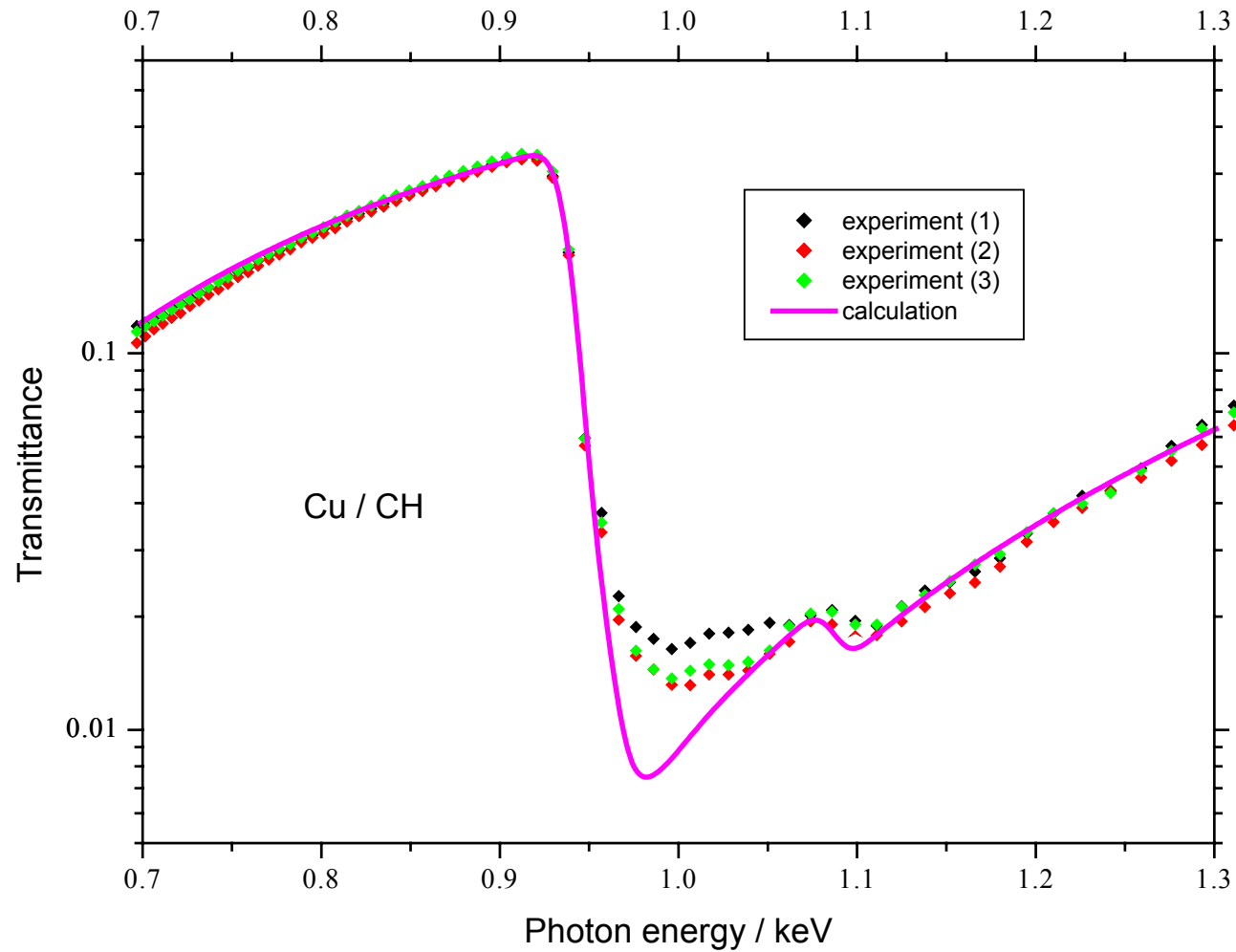
This work has been supported by the grant of International Science and Technology Center through the Project #2500 «Calibration of the Space Solar Patrol apparatus at the synchrotron source». The authors are grateful to foreign partners of the project: A. Aylward (UK), J.-P. Delaboudiniere (France), A. Hilgers (Holland), N. Pailer, G. Schmidtke, F. Scholze, G. Ulm (Germany).



Measurements of the X-ray transmittance of filters



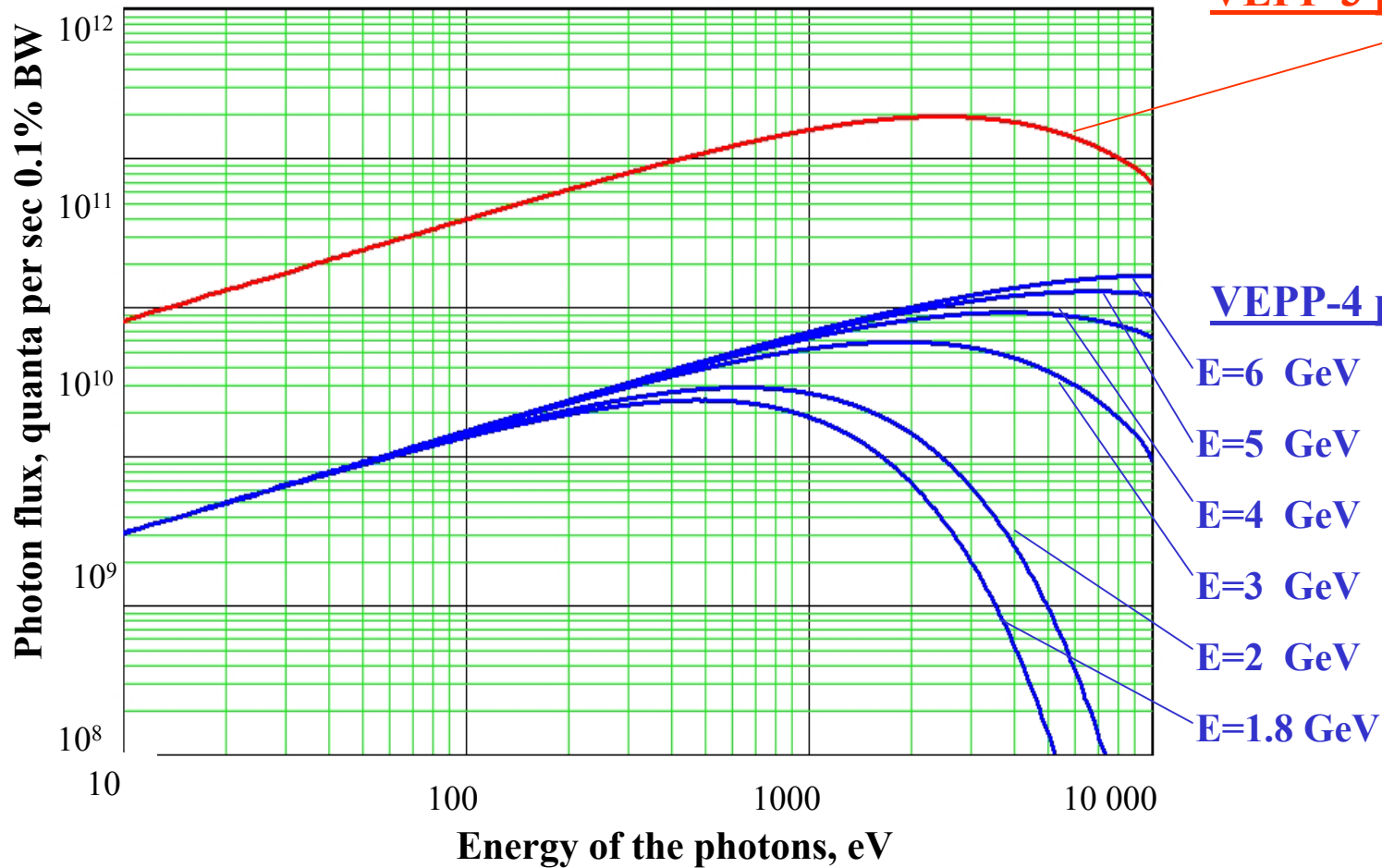
Experimental and calculated transmission of filter $\text{Cu}(0.42\mu\text{m}) + \text{CH}(0.15\mu\text{m})$



Comparison of the photon flux from the «Methrology» stations for of the VEPP-3 and VEPP-4 storage rings.

Beamline and monochromatization parameters:

aperture - 5X5 mm, bandwidth $\Delta E/E=10^{-3}$



VEPP-3 parameters:

Current:
I=10 mA,
Energy of electrons
E=2 GeV

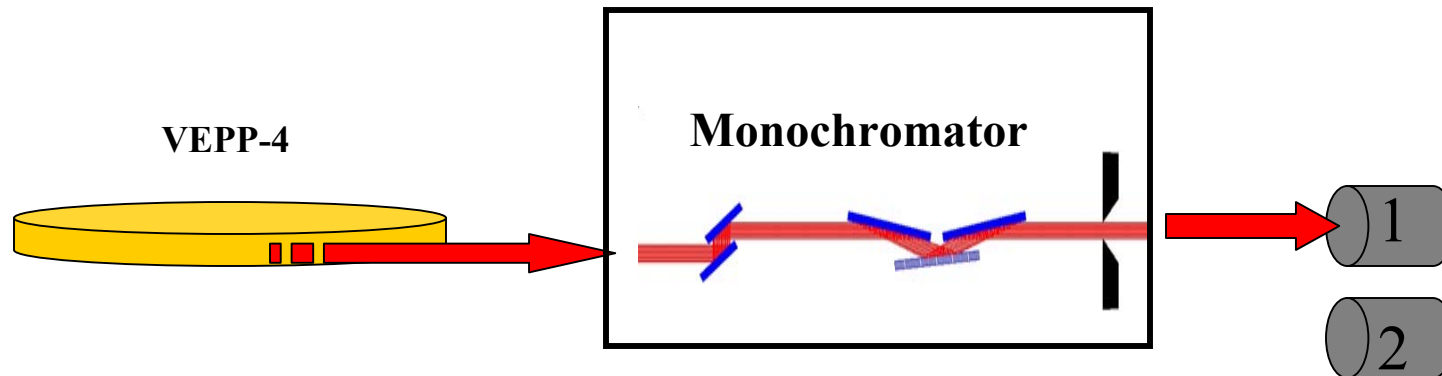
VEPP-4 parameters:

E=6 GeV
E=5 GeV
E=4 GeV
E=3 GeV
E=2 GeV
E=1.8 GeV

Current:
I=10 mA,
Energy of electrons
E=1.8 ... 6 GeV

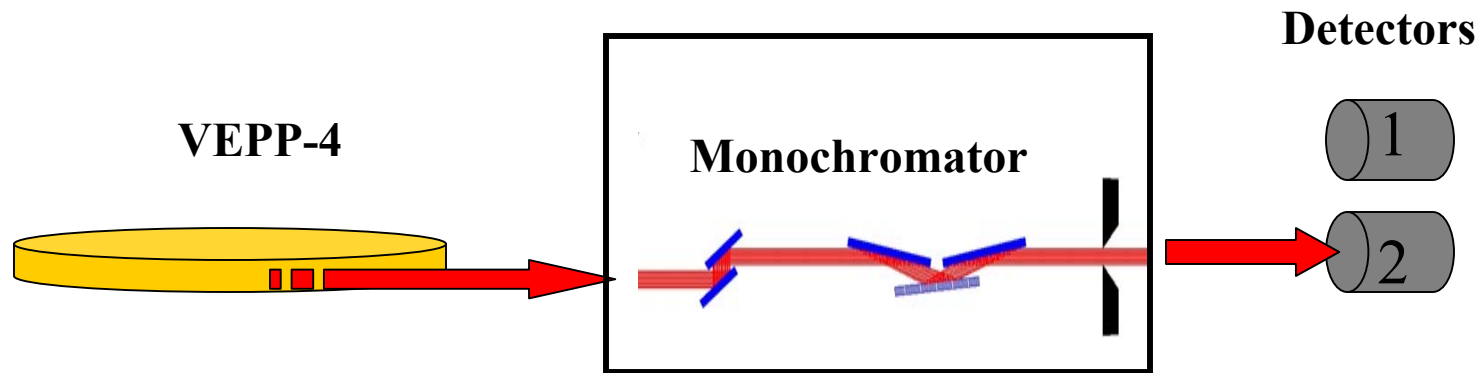
First step:

Creation of two detectors with the “identical” spectral characteristic



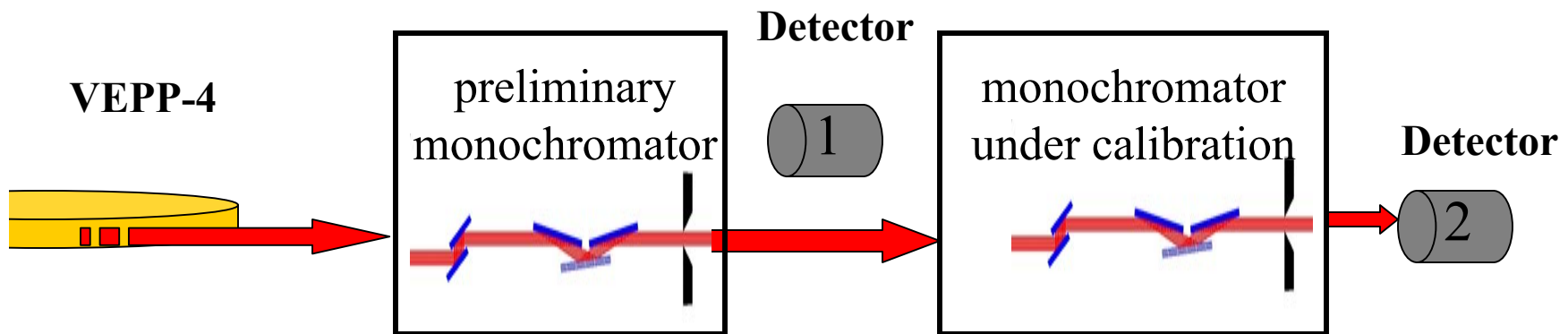
First step:

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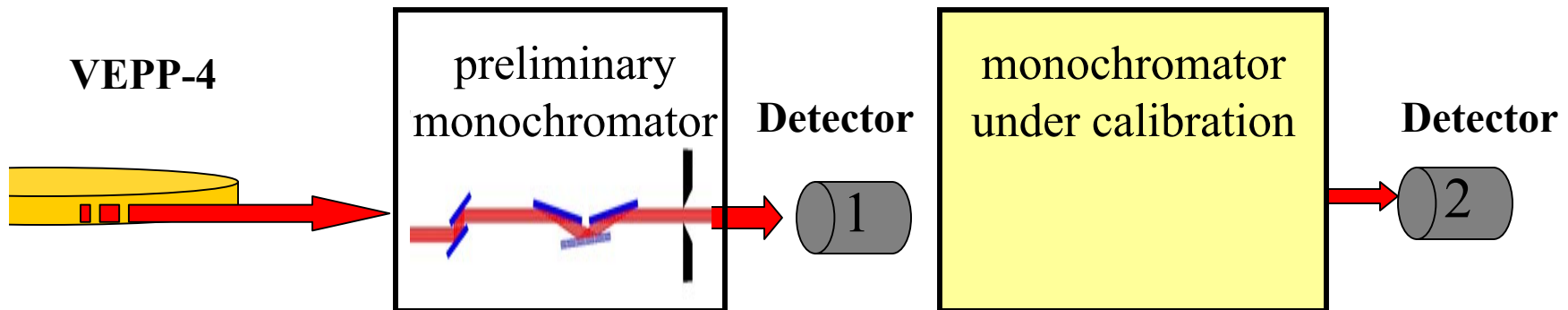
Second step:

Calibration of the monochromator



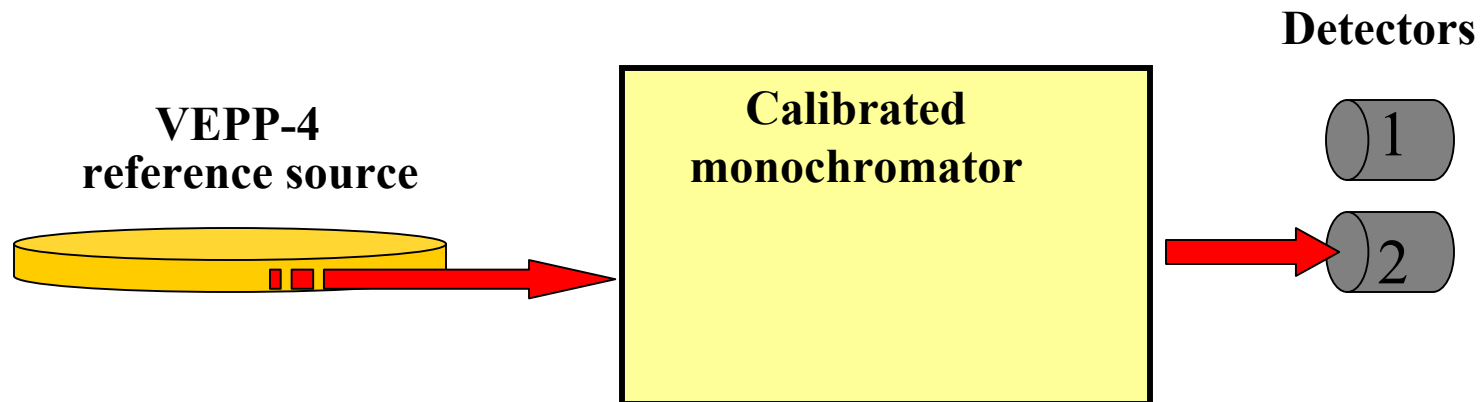
Second step:

Calibration of the monochromator



Third step:

Absolute calibration of the detectors using reference source



Third step:

Absolute calibration of the detectors using reference source

