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DESIGN OF A COMPACT SETUP TO MEASURE BEAM ENERGY BY DETECTION OF COMPTON BACKSCATTERED PHOTONS AT ANKA

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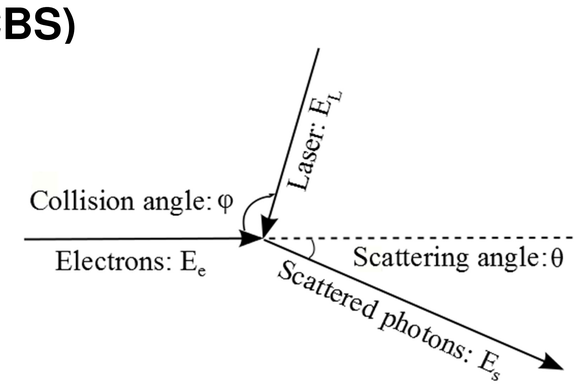
Abstract: One of the most important parameters of accelerators is beam energy. So far, the method of resonant spin depolarization was used to determine the energy at ~2.5 GeV of the ANKA electron storage ring. This, however, becomes cumbersome for lower energies. A good alternative is the detection of Compton backscattered (CBS) photons, generated by laser light scattered off the relativistic electron beam. To achieve a compact and integrated setup, a transverse scheme is proposed instead of the conventional head-on collision. Here we present a feasibility study with respect to the expected signal-to-noise ratio by comparing simulations of CBS photons with actual background radiation measurements.

Compton Backscattering (CBS)

$$E_s = \frac{E_L(1-\beta\cos\varphi)}{1-\beta\cos\theta+E_L/E_e[1-\cos(\theta-\varphi)]}$$

$$\rightarrow E_{max} \approx \frac{E_e^2}{E_e+\frac{m^2c^4}{4E_L\sin^2\frac{\varphi}{2}}} \quad (*)$$



(*) For: θ=0 (E_s reaches its maximum E_{max}), $E_e >> mc^2 >> E_L$ and φ>0 (conditions typically met at storage rings).

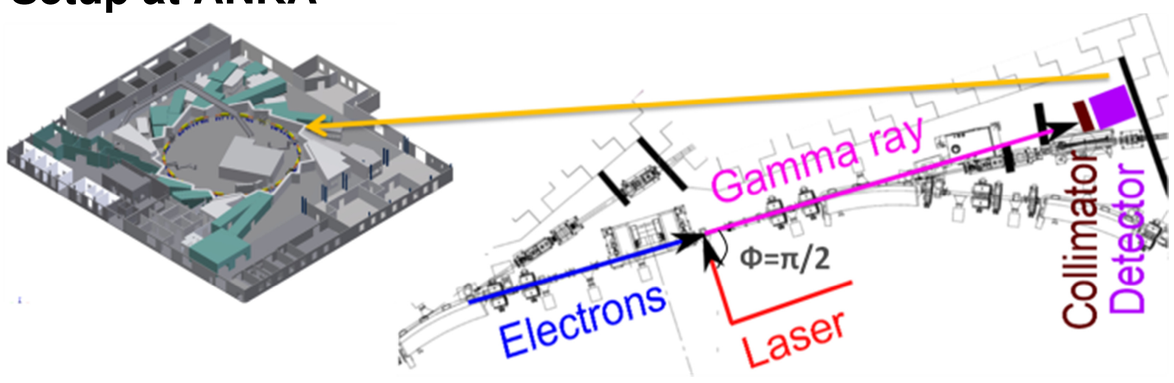
➢ With measured E_{max} & known mc^2, φ and E_L ➔ E_e can be determined.

Transverse Configuration (φ=π/2)

➢ Compared to conventional head-on collision based methods (φ=π):

Advantages	Challenges
Compact and integrated setup	Lower interaction time
Lower E_{max} ➔ Easier measurement	More sensitive to alignment errors
Versatile instrument	

Setup at ANKA



➢ High purity Ge (HPGe) spectrometer: high energy resolution (~10^{-3}).

➢ CW CO_2 laser (wavelength 10.6 μm, E_L 0.117 eV): E_{max} is within the sensitivity range of commercially available HPGe spectrometers.

➢ Collimator to reduce background level.

Measurement Accuracy

Accuracy of determining E_e (goal: a few10^{-4})

- The relative uncertainty of average E_{max}
- The relative uncertainty of E_L (< 10^{-5})
- The angular deviation σ_φ (~a few 10^{-4}, negligible for head-on collision)

- Systematically: energy calibration of the HPGe spectrometer (~a few 10^{-5} [1])
- Statistically: photon density at the cut-off edge [2]

[1] C. Sun et al., Phys. Rev. ST Accel. Beams 12, 062801 (2009).
[2] M.N. Achasov et al., the beam energy calibration system for the BEPC-II collider, arXiv: 0804.0159v1 (2008).

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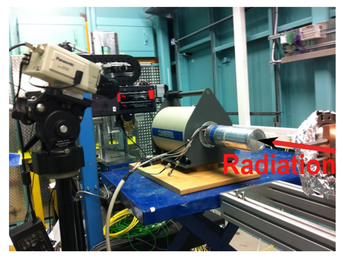
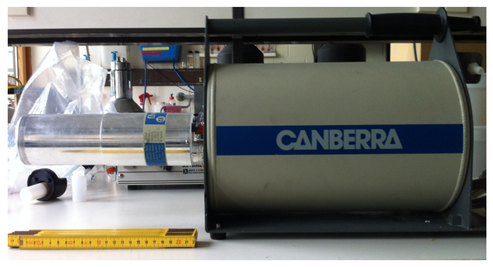
Signal-To-Noise Ratio

➢ Background measurement:

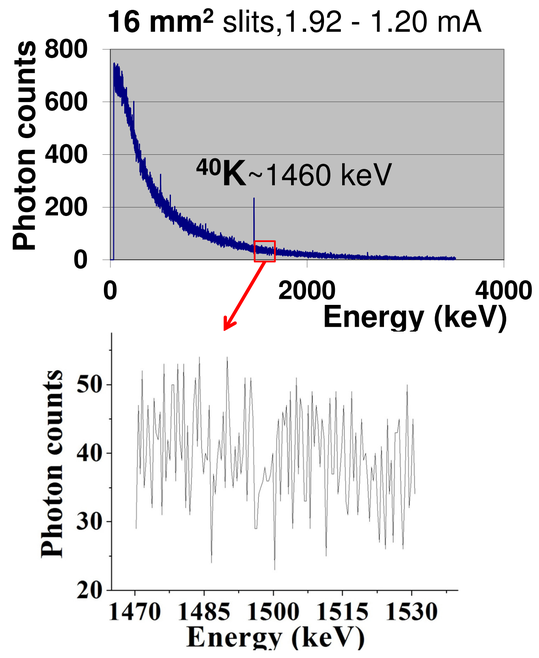
ANKA IMAGE beamline

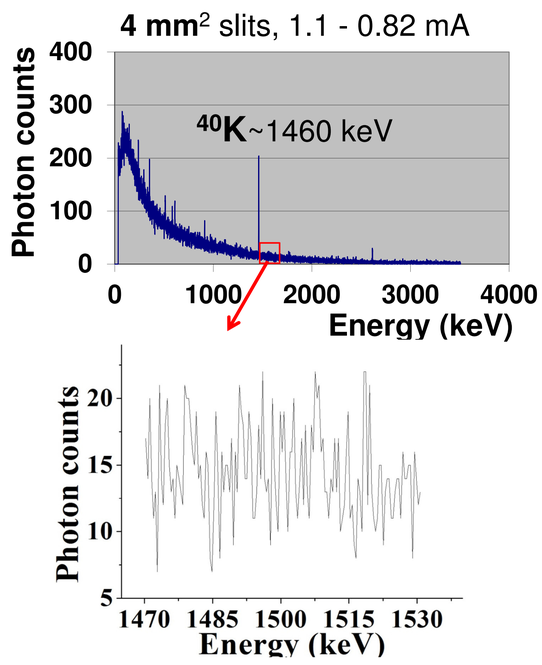




HPGe detector

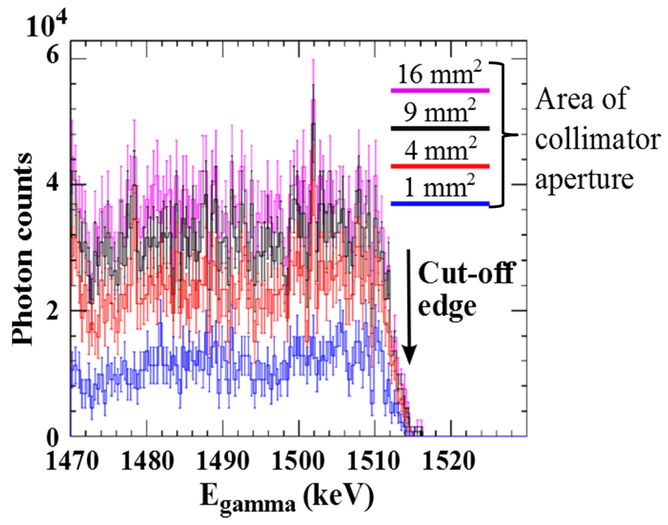
➢ Measurement results in low-α_c mode at 1.3 GeV for 2000s:





➢ Simulation of CBS photons reaching the detector:

- 40 mA electron beam
- 10 W laser
- 20 minutes acquisition time



➢ CBS photon & background radiation level proportional to electron beam current and detection time. A signal-to-noise ratio of ~2.5 is estimated.

Average photon count rate (photons/mA/s)		
Slits/collimator area	16 mm²	4 mm²
Background (**measured**)	**0.779**	**0.478**
Signal (**simulated**, ~5% detection efficiency)	**1.98**	**1.32**

Summary

➢ For the first time, an electron energy measurement setup based on a transverse CBS scheme is adopted at ANKA for its high usability and compactness.

➢ Background measurements and simulations with typical parameters have indicated that we can expect a signal-to-noise ratio exceeding 2.5 for the low-α_c mode at ANKA.

➢ The simulations indicate that the photon density at the spectrum edge is sufficient to reduce the statistic relative uncertainty of E_{max} to a few10^{-5}.

➢ For transverse geometries, the collision angle accuracy is most likely the limiting parameter, whereas for head-on collision schemes the absolute energy calibration of the HPGe detector is the most challenging factor.