# ILC BEAM ENERGY MEASUREMENTS BASED ON SYNCHROTRON RADIATION FROM MAGNETIC SPECTROMETER

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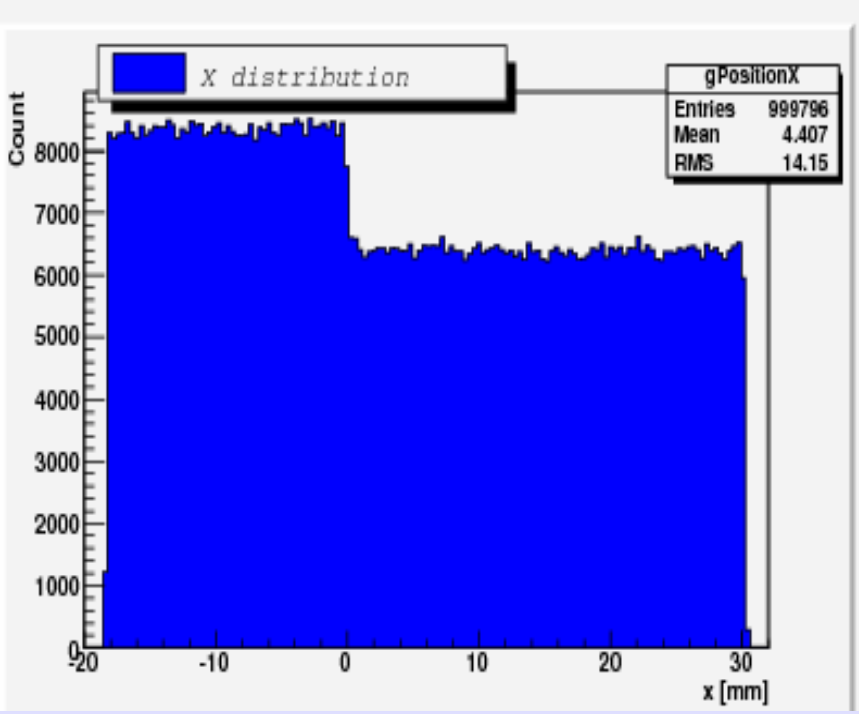
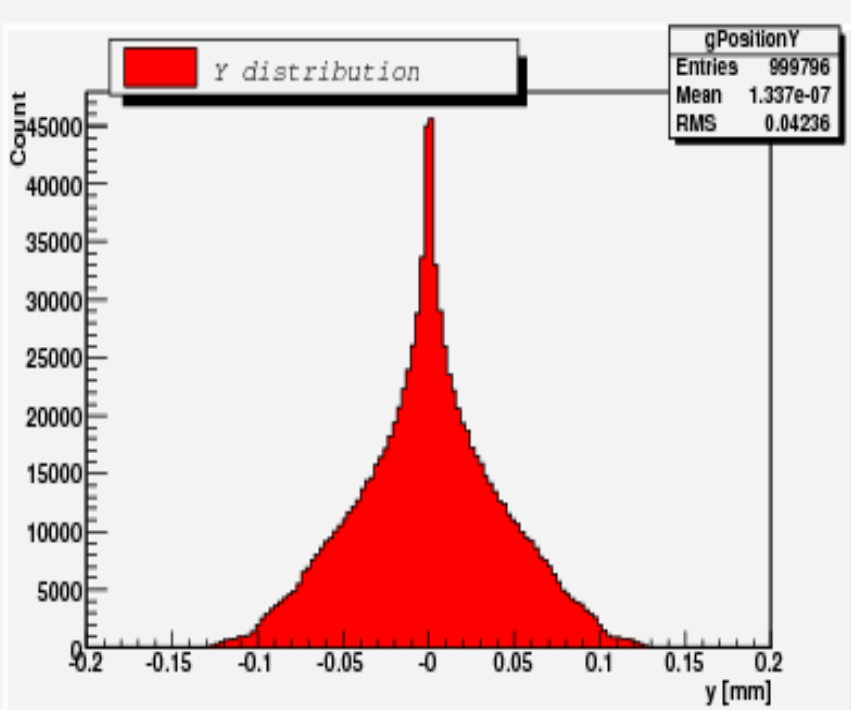
# SR photons distribution versus X, Y at the distance of 50 m



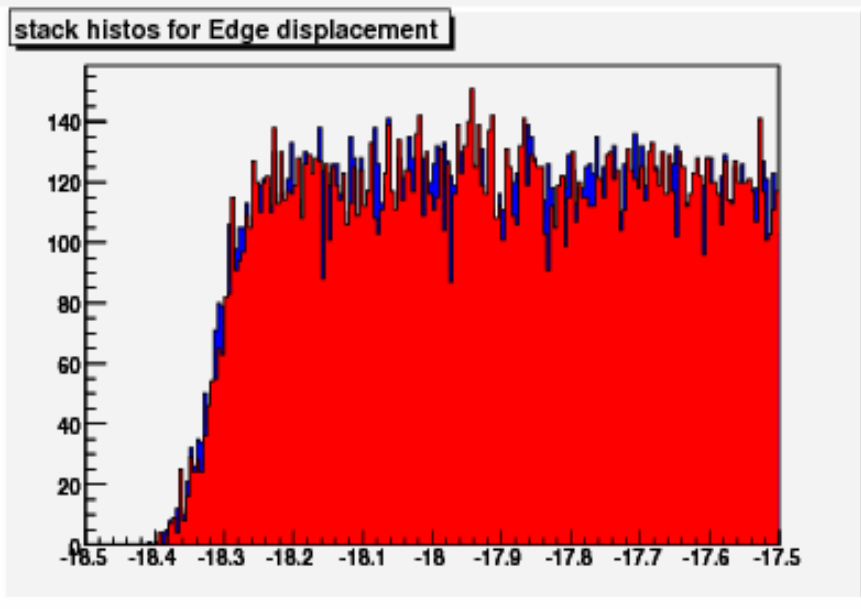



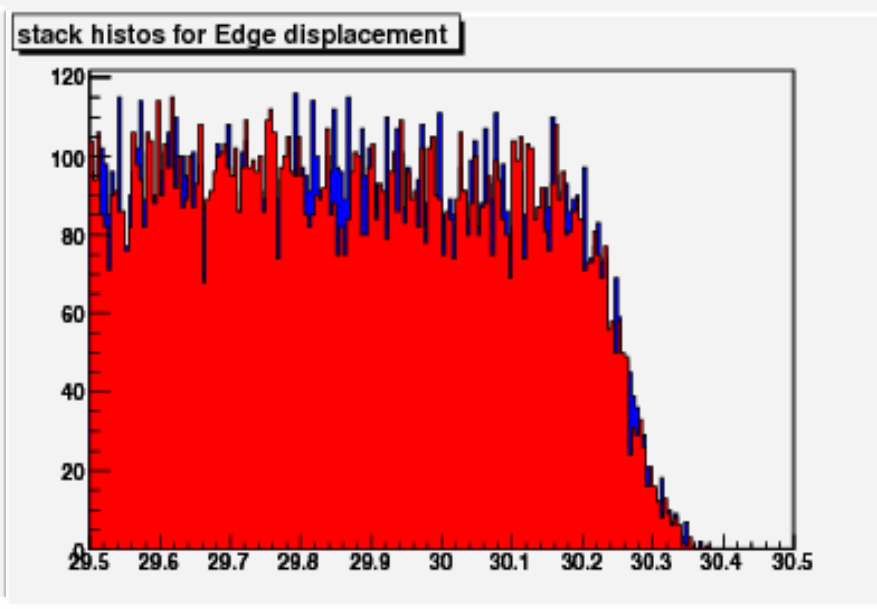

Beam energy: 250 GeV, Number of electrons: 100 000

# GEANT4 SIMULATION

**R. Makarov**

Right and Left SR spot width displacement.




**E=250 GeV - 50 MeV- blue histogram.**

**E=250 GeV-red histogram.**

| | |
|---|---|
| **SR fan left edge displacement** | **$\Delta x_{left} \approx 7\text{-}8$ μm** |
| **SR fan right displacement** | **$\Delta x_{right} \approx 5\text{-}6$ μm** |
| **Simulated energy resolution** | **12 μm/50 MeV** |
| **Required resolution** | **2.5 μm/50 MeV** |

# SIZE OF SR DETECTOR

- **Electron energy spread in bunch**

$$\Delta E / E \approx 10^{-3}$$

$$\Delta x^{E}{}_{edge} \approx L_1 \theta / 2 \cdot \Delta E / E \approx \mathbf{25}\ \mu\mathbf{m}.$$

- **Soft photon angle spread**

$$\theta_{sr} \approx 0.5 \cdot (\lambda / R)^{1/3} \approx \mathbf{12\ \mu rad\ at\ photon\ energy\ 20\ keV\ and\ electron\ energy\ of\ 250\ GeV.}$$

$$\Delta x^{SR}{}_{edge} \approx L_1 \theta_{sr} \approx \mathbf{750\ \mu m}$$

- **Fringe field in the magnetic rigidity at magnetic field variation of**

$$\Delta B / B > 1\%$$

***Δ(Bl)/Bl* ≈ 4·10$^{-2}$**

$$\Delta x^{R}{}_{edge} \approx L_1 \theta / 2 \cdot \Delta(B \cdot l) / (2 \cdot B \cdot l) \approx \mathbf{600\ \mu m}$$

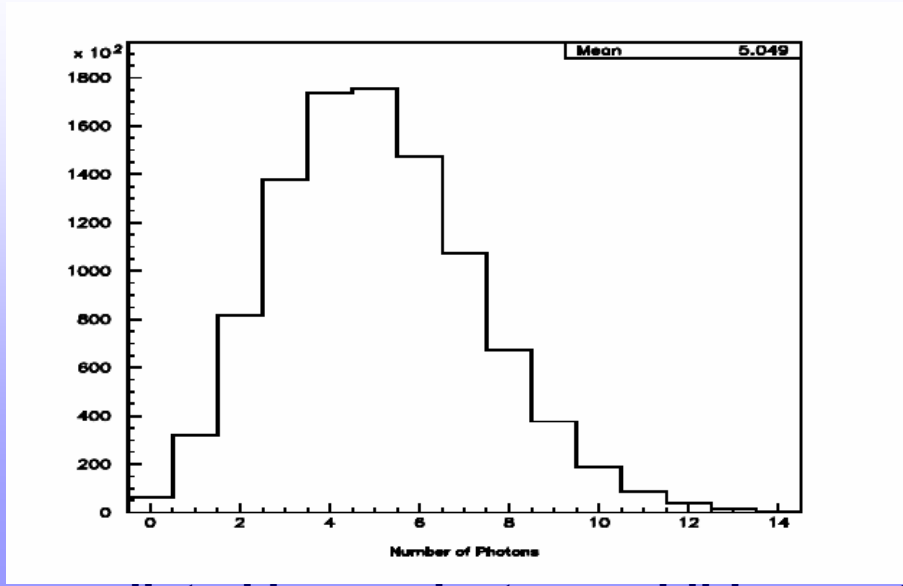
- **Interaction of hard SR photons with a vacuum pipe material became to additional SR at low energy and an increase of the SR fan horizontal size.**

$$\Delta x_{edge} \approx \left( \Delta x^{E}{}_{edge}{}^{2} + \Delta x^{R}{}_{edge}{}^{2} + \Delta x^{SR}{}_{edge}{}^{2} \right)^{1/2} \approx \mathbf{1mm.}$$

**The horizontal width of active detector area has been comparable with 1 mm at registration of soft SR.**

# GEANT SIMULATION

**K.H. Hiller**




**Multiplicity of photons radiated by an electron whihin spectrometer magnet, GEANT simulation**

$$\langle N_\gamma \rangle = 5$$

**Average number of photons radiated by one electron**

$$\langle E_\lambda \rangle = 3.8\ MeV$$

**Average photon energy**

**SR calculations**

**$<N\gamma>=(5/2\cdot 3^{1/2})\cdot\alpha\cdot eB/m\cdot L_{mag}/c=4.8$**

**$\alpha=1/137.$**

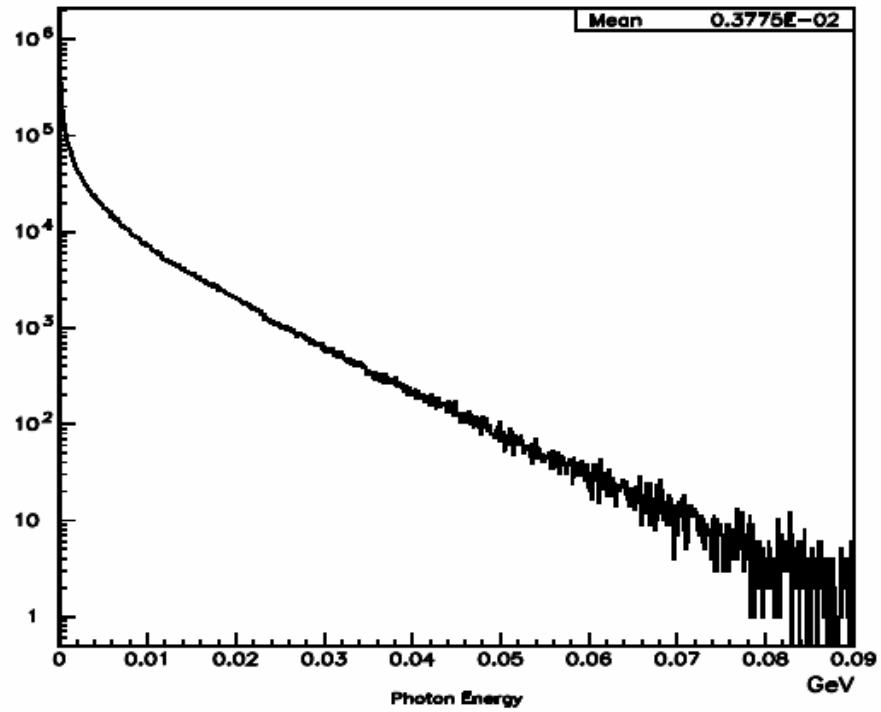
**$<E_\gamma>=(8\cdot 3^{1/2}/45)\cdot E_{cr}=3.6$ MeV**

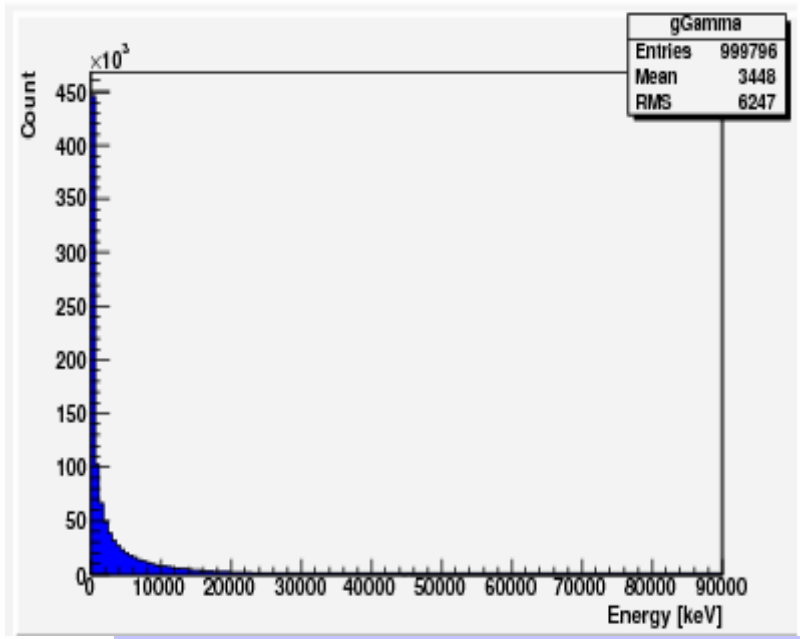
**$E_{cr}=0.66\ E_e^2(GeV)\cdot B(T)=11.6$ MeV- critical photon energy**

# PHOTON ENERGY SPECTRUM

**K.H. Hiller**

R. Makarov



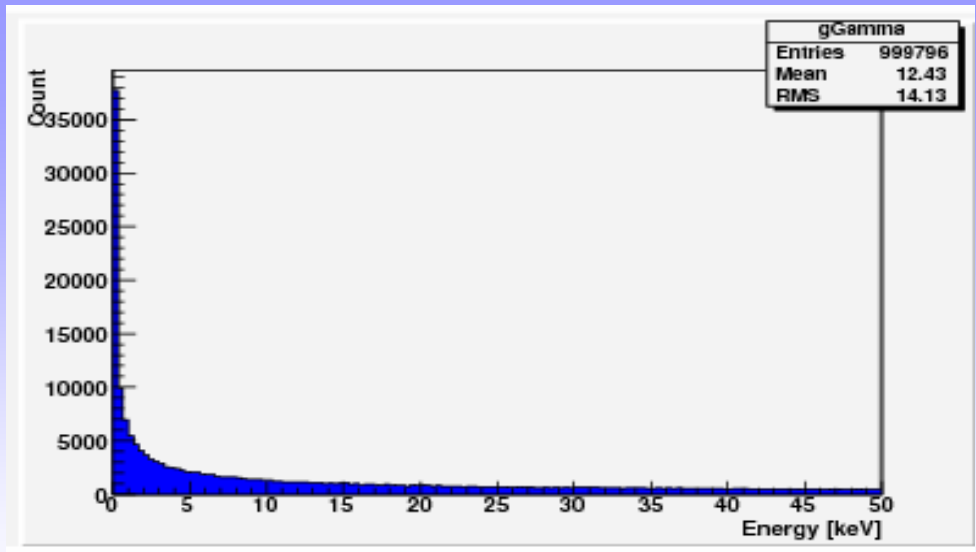




**Energy of photons radiated within the spectrometer magnet.**

Energy of photons radiated within all 3 magnets.

# Energy Spectra Comparison.

| Energy range [keV] | | Fraction % | | | |
|---|---|---|---|---|---|
| | Theory | GEANT4 | GEANT3 | T vs G4 | T vs G3 |
| 0..10 | 11,37 | 11,89 | 6,80 | 0,52425 | 4,57 |
| 10..20 | 2,95 | 3,02 | 3,20 | 0,06688 | 0,25 |
| 0..100 | 24,50 | 25,28 | 20,20 | 0,77746 | 4,3 |
| 100..200 | 6,37 | 6,36 | 6,70 | 0,00569 | 0,33 |
| 200..300 | 4,46 | 4,33 | 4,50 | 0,12503 | 0,04 |
| 300..400 | 3,55 | 3,39 | 3,60 | 0,16011 | 0,05 |
| 400..500 | 3,00 | 2,81 | 3,00 | 0,19026 | 0 |

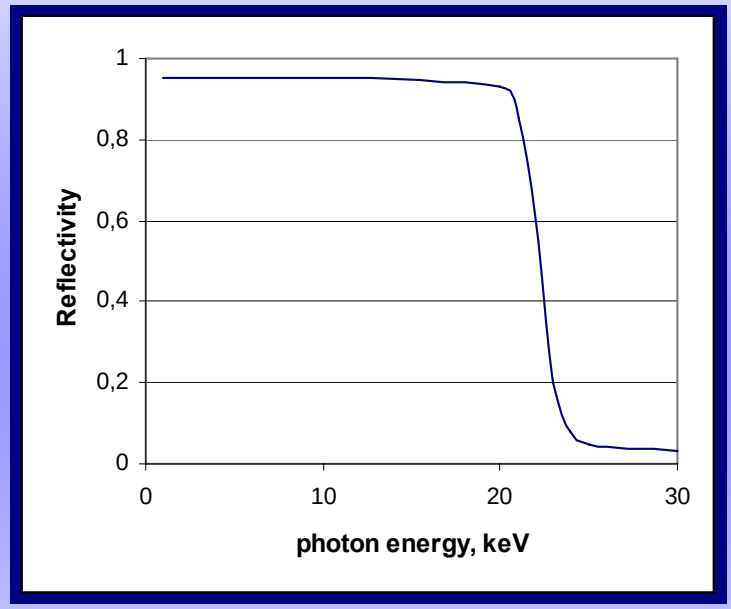



Energy spectra of low energy SR photons, GEANT4.

# REFLECTION OF SOFT SR RADIATION BY MIRROR

$\varphi_{max}$ *(rad)* ≈ 0.08/$E_\gamma$ *(keV)*=4 mrad

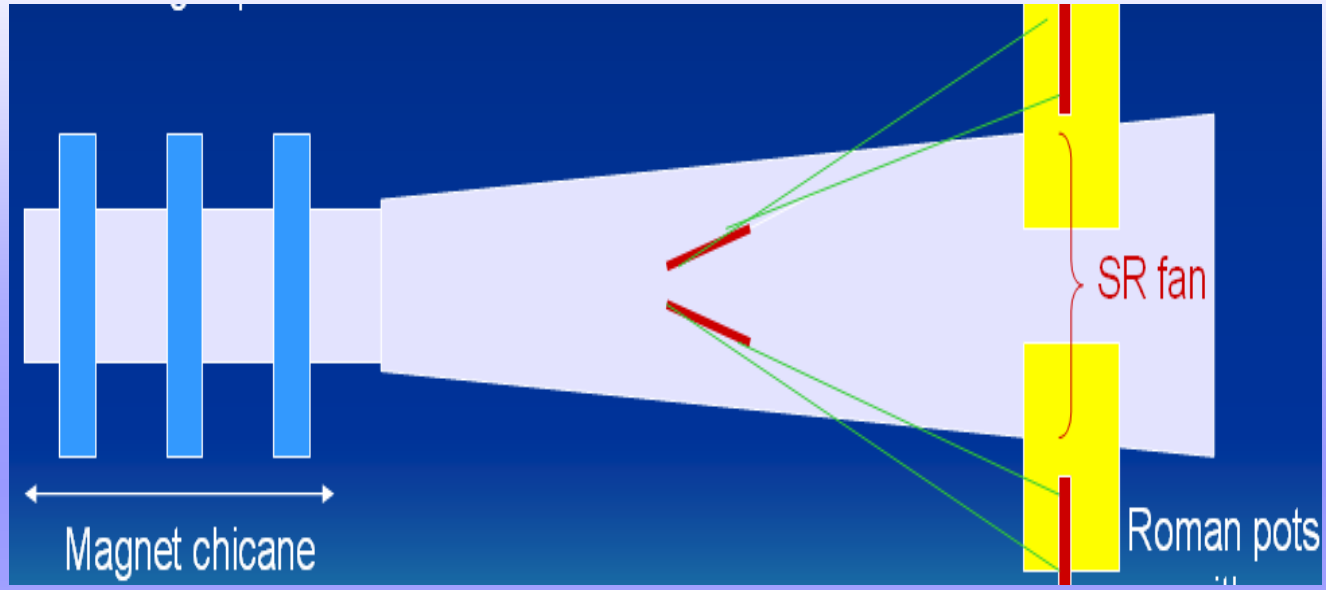
**mirror critical angle at large atomic number Z and electron energy of 20 keV**




**Dependence of Rh mirror reflectivity on photon energy.**

**The mirror reflected surface is placed at angle of φ=3 mrad to beam axis.**

# REFLECTION MIRRORS FOR SOFT SR




**The application of mirrors permits to avoid the problems related to SR radiation protection however the installation of mirrors reduces the energy resolution at fixed coordinate resolution and detector position.**

**$L_{am}$=40 m**

**mirror-spectrometer magnet distance**

**$L_{m\text{-}d}$=10 m**

**mirror-detector distance**

# DETECTOR SHIELDING AT MIRROR SCHEME

**The coordinate of left SR spot edge is equal to**

$$x_L = (LLA + LAM/2 + L_{a-m}) \cdot \theta/2 + L_{m-d} \cdot (2\varphi - \theta/2)$$ **=8.3 cm.**

**The coordinate of left hard SR spot edge corresponds to**

$$x_{SR}=3.1 \text{ cm.}$$

**The distance about**

$$\Delta x = 5 \text{ cm}$$

**between soft SR channel and ILC beam pipe can be used for detector shielding and reduction of hard SR intensity.**

**In this case we assume that before mirror the horizontal size of vacuum chamber pipe can be increased from 4 cm up 7 cm on a length of 40 m from middle of analyzed magnet.**

**After mirror two special channels of length 10 m will be constructed to transportation of soft SR radiation to detector.**

# ENERGY RESOLUTION IN MIRROR SCHEME

$$\frac{\delta E}{E} = \frac{\delta x_L}{(L_1 - L_{m-d1})\theta / 2} \quad = 1 \cdot 10^{-4}$$

**at detector coordinate resolution of δ*x*=2 μm.**

**MIRROR PARAMETERS**

**mirror thickness $d_{mir} \approx 25\text{-}50$ μm**

$$y \approx L_1 \cdot \theta_{sr} \approx \text{ 0.6 mm}$$

**vertical size of SR spot on mirror**

$$l_{mir} = (LAM + L_{a\text{-}m})\ 0.1\theta/2\varphi = 65 \text{ cm}$$

**length of left mirror**

**The mirror reflect soft SR photons generated inside analyzing magnet on length of 0.1 LMM≈ 30 cm at deflection angle of 0.1 θ/2≈0.05 mrad.**

# Main results of JINR-Zeuthen collaboration in 2006

1. Proposed two schemes applied for electron/positron energy measurements in ILC based on SR produced in magnetic spectrometer.
2. Performed GEANT simulations permits to achieve a sensitivity of 10 μm/25 MeV. Scaling this sensitivity to a detector with spatial resolution of 2 μm permits to reach an energy uncertainty of $\Delta E/E$, better than $10^{-4}$ for the nominal 250 GeV ILC beam energy.
3. Proposed two strip detectors, applied for measurements of SR spot position with resolution of 2-3 μm.
4. A prototype of a gas amplification strip detector with 47 channels and resolution of 3 μm was constructed. A design of high pressure (150 atm) chamber for a gas amplification strip detector was performed. The construction of high pressures chamber is planed up to end 2006.

**Publication in 2006**


*1. K. Hiller, H.J. Schreiber, R. Makarov, E. Syresin, B. Zalikhanov, ILC Beam energy measurement based on synchrotron radiation from a magnetic spectrometer, X European Particle Accelerator Conference, Edinburgh, 2006, p.2442-2444.*

*2. K. Hiller, H.J. Schreiber, R. Makarov, E. Syresin, B. Zalikhanov, Possibility of Beam Energy Measurements Based on Synchrotron Radiation from ILC Magnet Spectrometer. EUROTeV-Report-2006-091.*

*3. K. Hiller, H.J. Schreiber, R. Makarov, E. Syresin, B. Zalikhanov ILC Beam Energy Measurement based on Synchrotron Radiation from a Magnetic Spectrometer, LC-DET-007, 2006, p.16*

# Activity proposed in 2007

1. JINR experts participate in GEANT simulations of SR produced in energy spectrometer.

2. GEANT simulation of conversion efficiency of $\gamma$-quanta in photo electrons in gas amplification detector.

3. Development and construction of electronics for a prototype of gas amplification detector with resolution of 3 $\mu$m.

4. Calibration of prototype of gas amplification detector.

**Required resources in 2007 for prototype of SR coordinate detector: 13.5 k$**

# Conclusion

- **The position measurements of both horizontal edges for SR fan permits to determine the beam energy with a resolution of $\Delta E/E \cong 5 \cdot 10^{-5}$.**

- **The energy resolution obtained in GEANT simulations corresponds to 10μm/25 MeV at electron energy of 250 GeV. This scaling sensitivity permits to reach the energy resolution of $\Delta E/E \approx 5 \cdot 10^{-5}$ at spatial resolution of 2-3 μm.**

- **A prototype of a gas amplification detector with a high position resolution of 3 μm for a low energy gamma registration within large radiation background are constructed now.**