Some points for discussion on the SR paper

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ILC Beam Energy Measurement based on Synchrotron Radiation from a Magnetic Spectrometer

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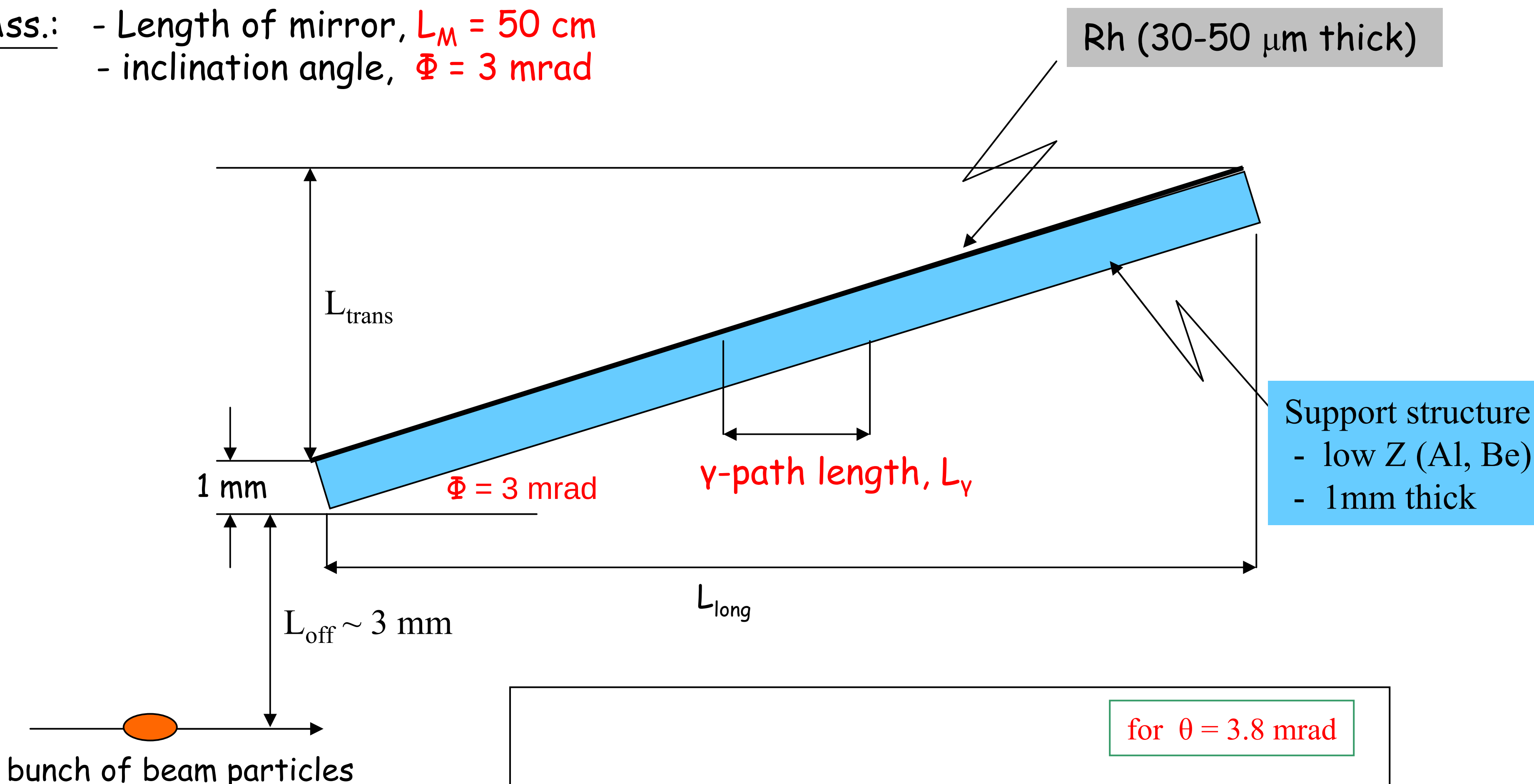
Abstract

We propose to measure, on a bunch-to-bunch basis, the beam energy at the International Linear e^+e^- Collider by monitoring synchrotron radiation (SR) light emitted in the magnets of an energy spectrometer based on beam position monitors. Measuring the width of the horizontal SR fan permits to determine the relative beam energy with a precision better than 10^{-4}. There are two different measuring schemes possible. The first one is based on edge measurements of the direct SR fan, while the second option includes mirrors to deflect soft SR light to detectors located far from the beamline. For high-spatial resolution detectors three possibilities are under discussion: a silicon strip detector, a novel-type Si detector with exceptional position resolution and a gas amplification detector. The main problem of the first scheme is the high radiation dose expected in the direct SR fan. If mirrors are used this dose is strongly reduced if the mirrors resist the heat load. The novel-type Si and gas amplification detectors needs further R&D to be realized.

MIRROR

Ass.: - Length of mirror, L_M = 50 cm
- inclination angle, Φ = 3 mrad



for θ = 3.8 mrad

$L_{trans} = L_M \cdot \sin(0.003) = 1.5$ mm (1.9 mm) !
$L_{long} = L_M \cdot \cos(0.003) = 500$ mm (500 mm)
$L_\gamma = 1\text{ mm} / \sin(0.003) = 333$ mm (263 mm) !

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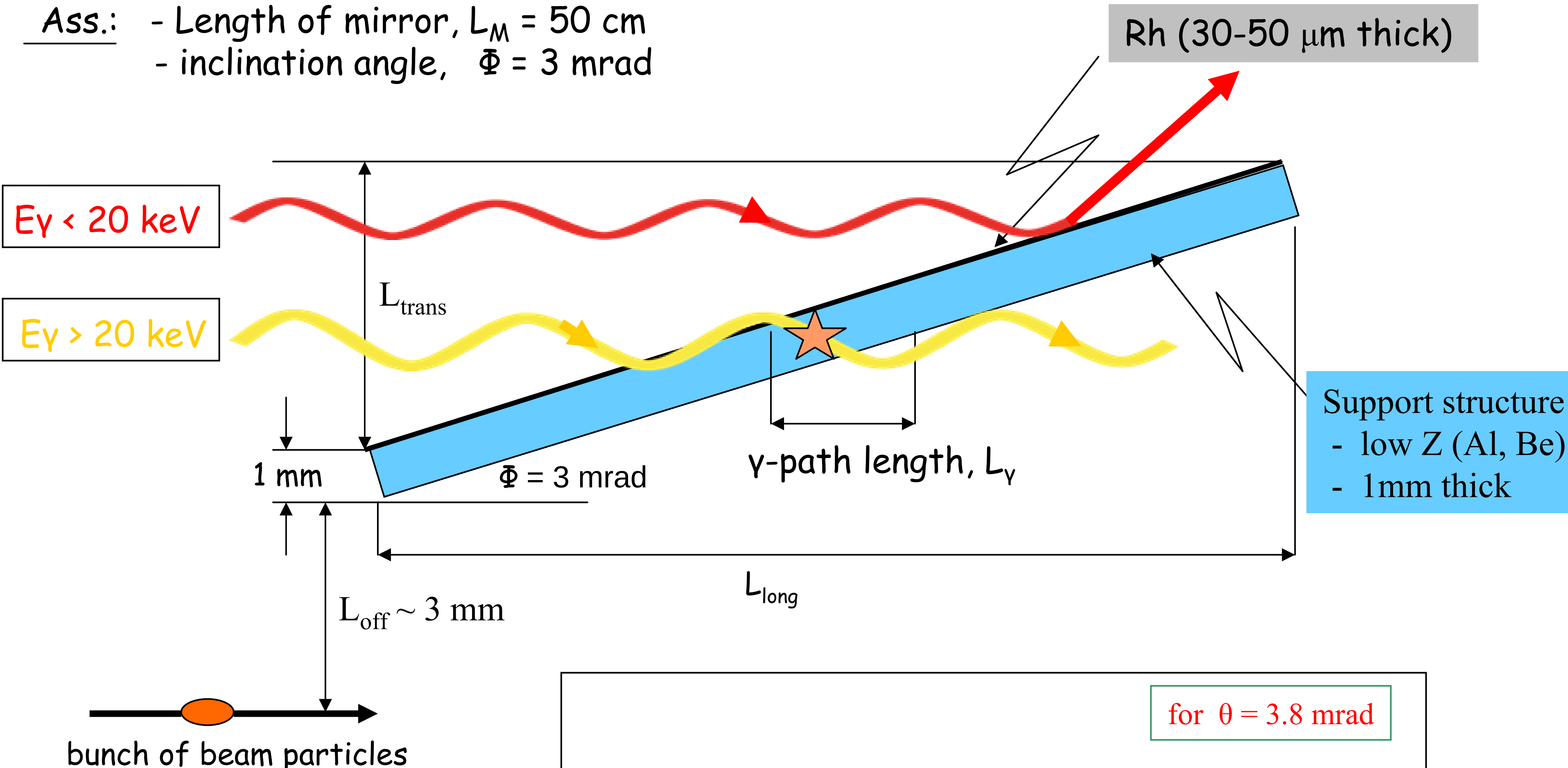

for $\theta = 3.8$ mrad

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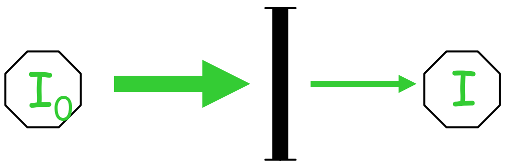
Absorption of light in material



$$I = I_0 * \exp\{-\mu\rho d\}$$

μ - absorption coefficient [cm^2/g]
ρ – density of material [g/cm^3]
d – thickness of material [cm]

For aluminum (ρ=2.70 g/cm3) and a thickness of 33 cm

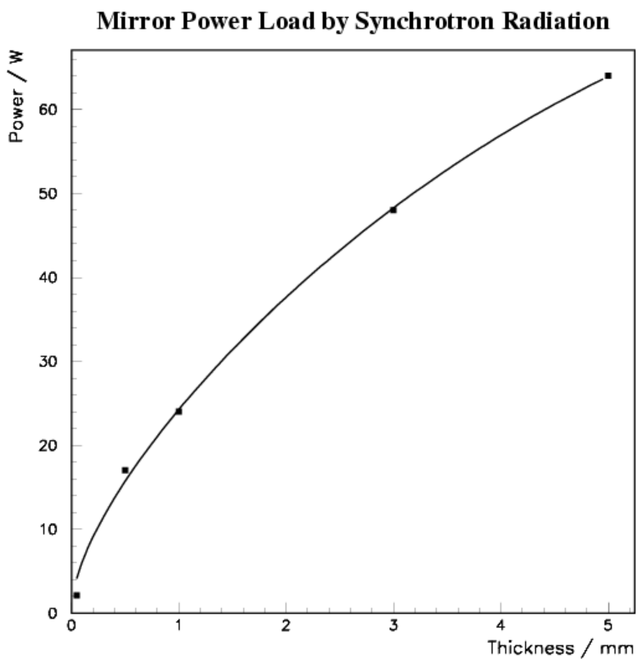
E_γ	abs. coeff	I/I_0=1
0.1 keV	~10^4	0
1	~10^3	0
2	~8 10^3	0
5	~10^2	0
10	26.2	0
20	3.44	0
50	0.37	0
100	0.17	0.26 10^-6
200	0.12	0.23 10^-4
500	0.084	0.56 10^-3
1 MeV	0.0615	0.42 10^-2
5	0.0284	0.080
10	0.0232	0.13

- Photons with Eγ < 20 keV, if not reflected, completely absorbed

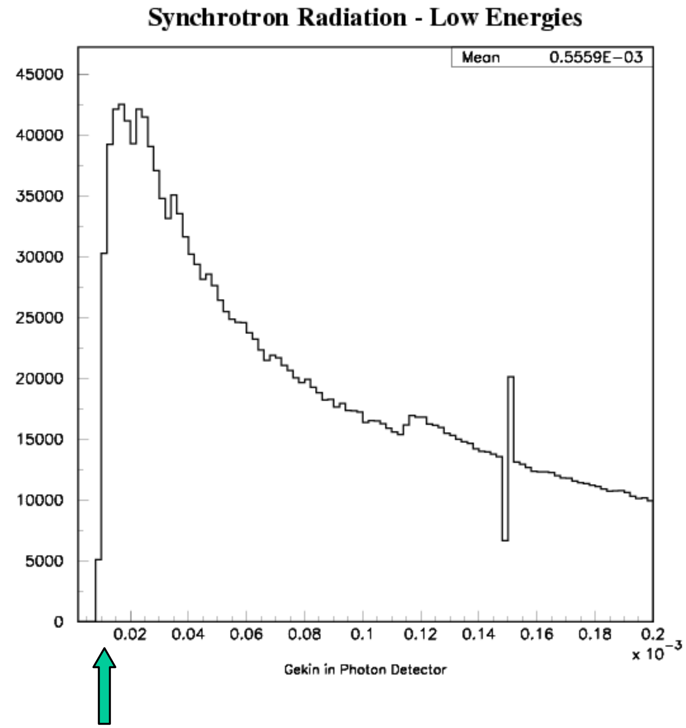
- Photons with larger energies (up to ~10 MeV), almost all absorbed by Al support for the mirror of 1mm

- some heat load of 15-20 Watt is expected → consequences ? first rough design of mirror system (with cooling ?) is needed

GEANT3 simulations of Karlheinz



Fe assumed
for the mirror



? Cut-off gamma energy =
10 keV

GEANT4 ?

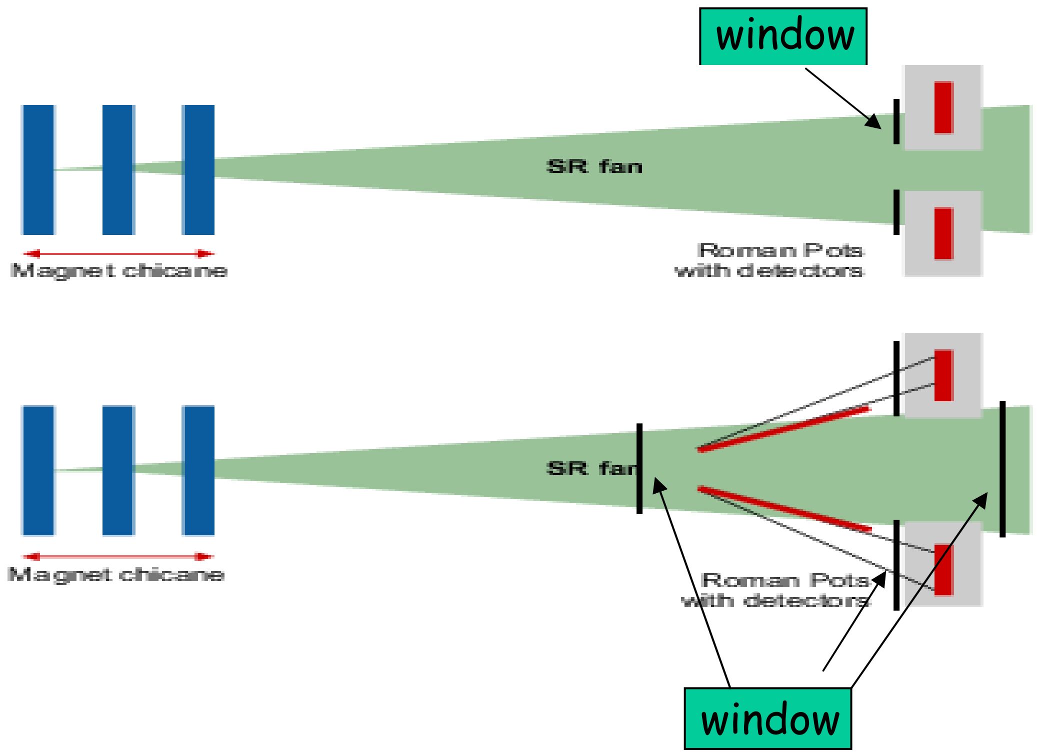
SR light passes a thin window

might be needed for separation of the Roman Pots from the vacuum system

or if a separate vacuum chamber for the mirror system is required

scheme 1

scheme 2



Thus, at least 1 window will be passed by SR light

- window thickness ?

- window material ? → have to be studied

Assume **aluminum (Al) window of 100 μm** thickness:

E_γ	$I/I_0=1$
0.1 keV	0
1	0
2	0
5	0.7 10^-2
10	0.49
20	0.91
50	0.99
100	1
>100	1

- most photons with E_γ > 20 keV go through the window
  → **fine for scheme 1**

- but a large fraction of the SR (with E_γ < 10 keV) will be absorbed
  → **bad for the mirror scheme**

Solution: - try to push the value of 'absorption' energy from 10 down to 1 keV by using very low Z material (Be?) and/or reduce the window thickness substantially

Examples:

- 100 μm thick Al window → 50 μm Al window:

  ➔ SR with $E < 2$ keV is absorbed

  ➔ 26 % instead of 0.7 % of SR with 5 keV energy passes the window

  ➔ most of the SR with $E > 10$ keV passes the window

→ is that amount of remaining SR sufficient
for efficient its detection ?

- Be window of 100 μm:

  ➔ 75 % of SR with $E = 2$ keV is absorbed

  ➔ 92 % of SR with 5 keV passes the window

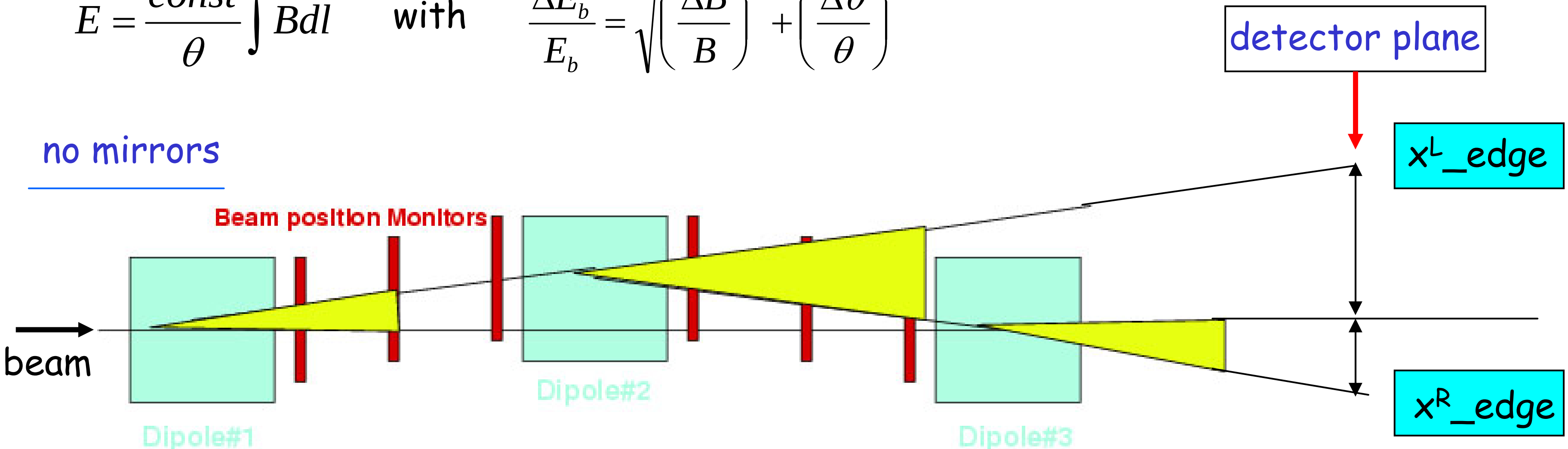
  ➔ 99 % of SR with $E > 10$ keV passes the window

→ the situation is somewhat better, but not perfect

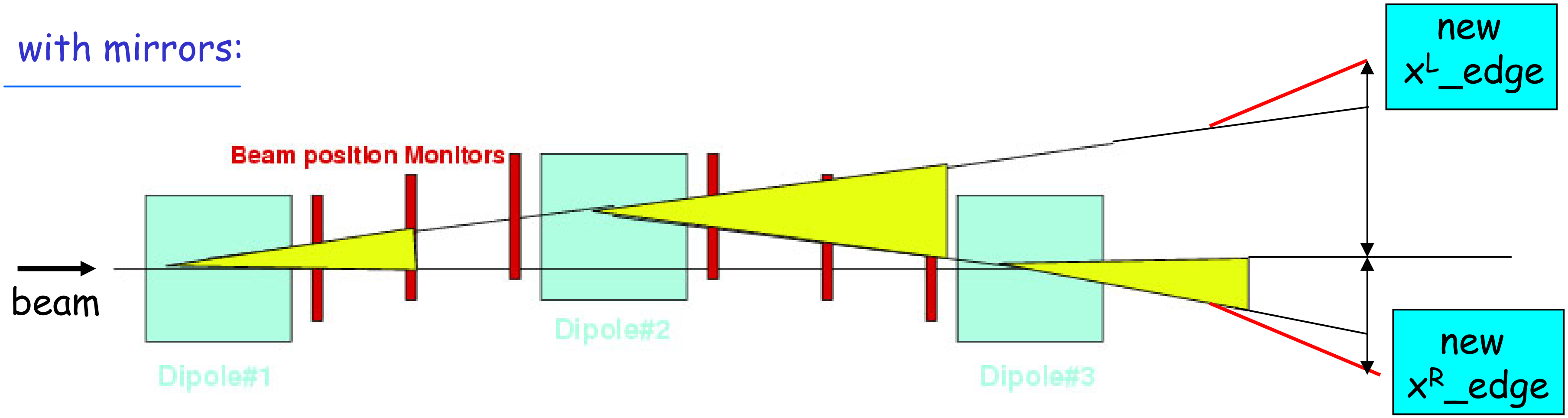
Is energy resolution degraded if mirrors are implemented in the set-up ?

$$E = \frac{const}{\theta}\int Bdl \quad \text{with} \quad \frac{\Delta E_b}{E_b} = \sqrt{\left(\frac{\Delta B}{B}\right)^2 + \left(\frac{\Delta\theta}{\theta}\right)^2}$$

no mirrors



with mirrors:



No mirror case:

Measuring both edge positions, x_left and x_right,

the bending angle Θ is expressed

$$\theta = \frac{x_L + x_R}{L_{tot}}$$

with L_{tot} = distance 'magnet-detector'

The uncertainty of Θ governed by
the uncertainties of x_left, x_rigth (=dx)
and that of L_{tot}

Mirror case:

$$\theta = \frac{x_L + x_R - 4L_3\Phi}{L_2 - L_3}$$

Θ is now a function of x_left, x_right,
and L_2, the distance 'magnet-mirror'
and in addition of L_3 (the distance 'mirror-detector')
and the mirror inclination angle Φ

Thus, two more quantities with errors entering Θ
→ increase of dΘ/Θ and therefore of dE_b/E_b

→ **case of mirrors degrades the beam energy resolution**

do we have a simple formula to estimate this degradation
which is also suitable to optimize the mirror set-up?

What about ground-motion of the magnets and detector ?

Uncorrelated motion/vibration of the magnets

in vertical direction -- no effect (?) → CHECK !

in horizontal direction -- steps, close edge regions of SR yield

→ needs some understanding

Vibration of detector -- no effect (?) on beam energy determination

since both x_left AND x_right are modified

in the same manner → CHECK !

What next ?

• draft

- idea, sketch of performance, feasibility (first GEANT simulation), possible detectors

- needs some points to be clarified

  → hope, most of them clarified during the meeting

- paper (on feasibility of the method) → ready in summer 2006

• R&D (detectors)

- R&D for detector(s), prototype tests ? -- load of SR ? -- ???

  in case of success:

  - based on new BPM-based energy spectrometer (~2008/2009 ?)

  - actual ILC beam delivery system (BDS)

    → design report (technical/conceptual ?) -- time window: ~2007 – 2009

- manpower ? financial support ?

Some conclusions

(to keep in mind in further studies)

Mirror:

- if Rh: Θ = 3 mrad → 3.8 mrad (max. possible value)
- mirror support: thin as possible (< 1 mm)
  and material with low Z (Be ?, wire system ?)
- other material with larger reflection angle Θ ?

'technical' design with a dedicated vacuum chamber necessary !

Window:

- if we restrict to SR with E < 20 keV (scheme 2)

a window with very small absorption probability

has to be chosen → which one ?

Detector R&D → Design Report in 2007 - 2009 ! ? Start to think about !