Comparison of 3- and 4-magnet-versions of the ILC energy spectrometers

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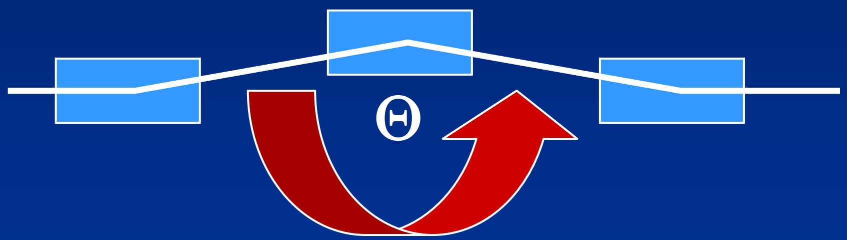
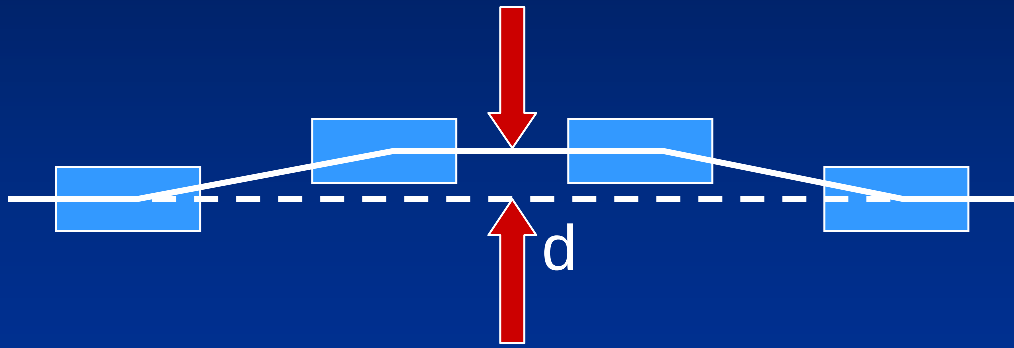




Measure the kink angle θ
of the electron trajectory

Measure the offset d in
respect to no magnetic field

Use Beam Position Monitors
➔ Compare E-resolution

To remind: 3-Magnet-Spectrometer

$$E = c \cdot Bl / \Theta$$

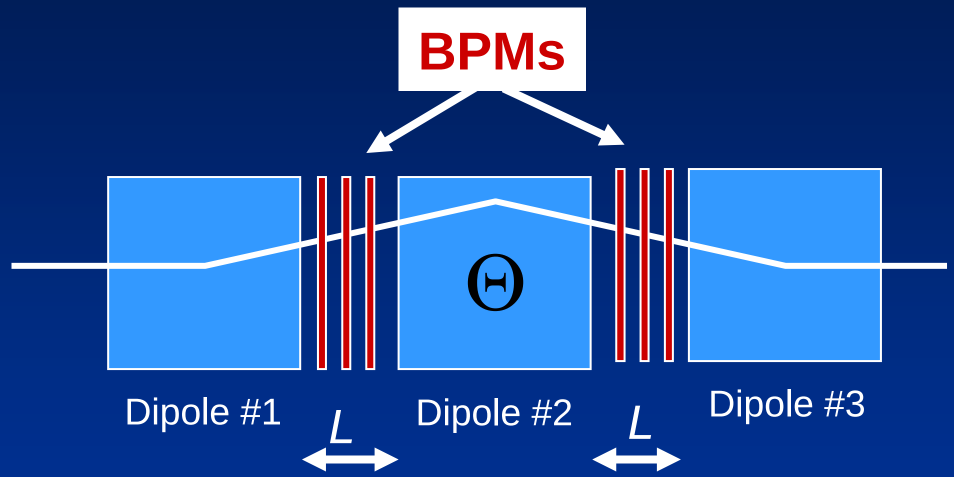
$$\left(\frac{\Delta E}{E}\right)^2 = \left(\frac{\Delta Bl}{Bl}\right)^2 + 2 f(N) \cdot \left(\frac{E \cdot \Delta x}{c \cdot L \cdot Bl}\right)^2$$

Bl ... analyzing field integral

$f(N)$ ... factor for N BPMs (2.0 ... 1.0)

Δx ... BPM resolution

L ... length of the measuring range



Instrumentation:

1) Analyzing magnet
   dipole #2 with integral field *Bl*

2) BPMs with resolution Δx to
   measure slopes of e-trajectory

Dipoles #2 and #3 not relevant
for Θ-measurement !!!

To remind: 3-Magnet-Spectrometer

For standard settings:

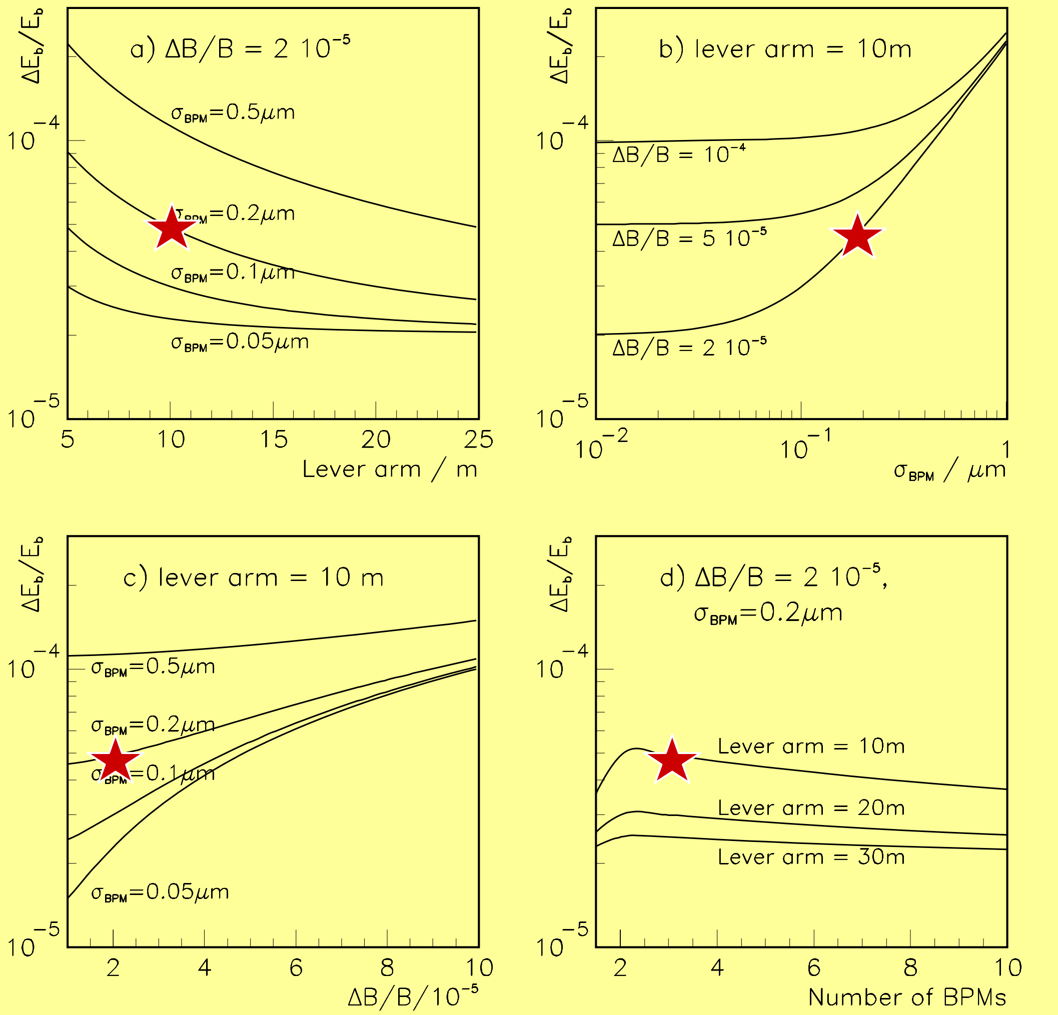
L = 10m
$\Delta B/B = 2\ 10^{-5}$
Δx = 200nm
BPMs = 3 …4

one obtains:

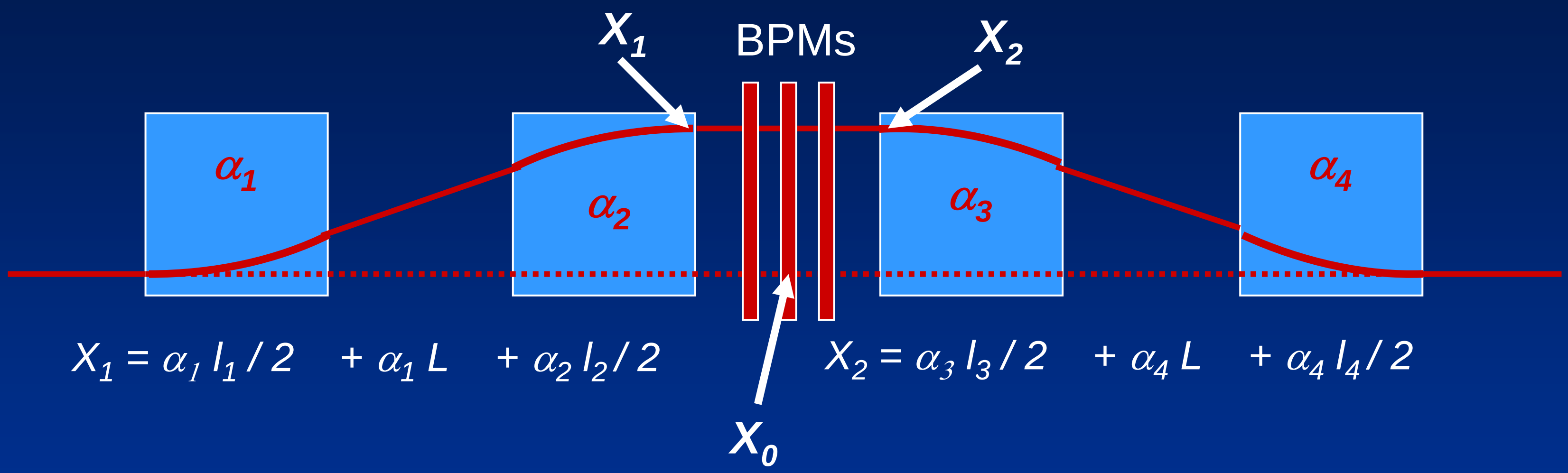
➔ $\Delta E/E \sim 5\ 10^{-5}$ ★

For more details see published ILC note LC-DET-2004-029

Energy Spectrometer Resolution - 3 Magnets



4 - Magnet - Spectrometer



$X = (X_1 + X_2) / 2 = (\alpha_1 l_1 + \alpha_2 l_2 + \alpha_3 l_3 + \alpha_4 l_4)/4 + (\alpha_1 L + \alpha_4 L) / 2$

Using a = c B l / E gives

$E = 1/X \; c/4 \; \{B_1 l_1 (l_1 + L) + B_2 l_2^2 + B_3 l_3^2 + B_4 l_4 (l_4 + L)\}$

- **→ all 4 magnets contribute to offset X and to E-measurement error**
- **→ Assumption BPM range > 5 mm !!!**

4 - Magnet - Spectrometer

… the partial derivatives gives the error of the E-measurement:

factor related to 2 measurements averaged over N BPMs

$$\left(\frac{\Delta E}{E}\right)^2 = \sum\left(\frac{\Delta Bl_i}{Bl_i}\right)^2 + 2/N\cdot\left(\frac{E\cdot\Delta x}{c\cdot\left(l+L/2\right)\cdot Bl}\right)^2$$

Bl_i … field integrals

N … number of BPMs

Δx … BPM resolution

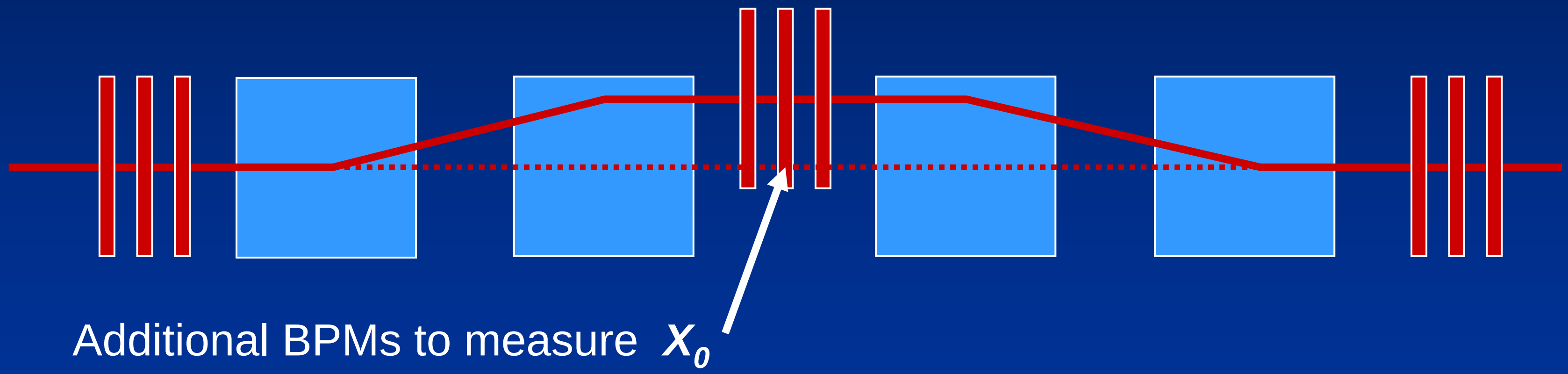
L … distance between magnets

l … magnet length $l_1 = l_2 = l_3 = l_4$

… for comparison we assume : $Bl_1 = Bl_2 = Bl_3 = Bl_4$

Beam jitter measurement

… version to take into account beam position jitters:

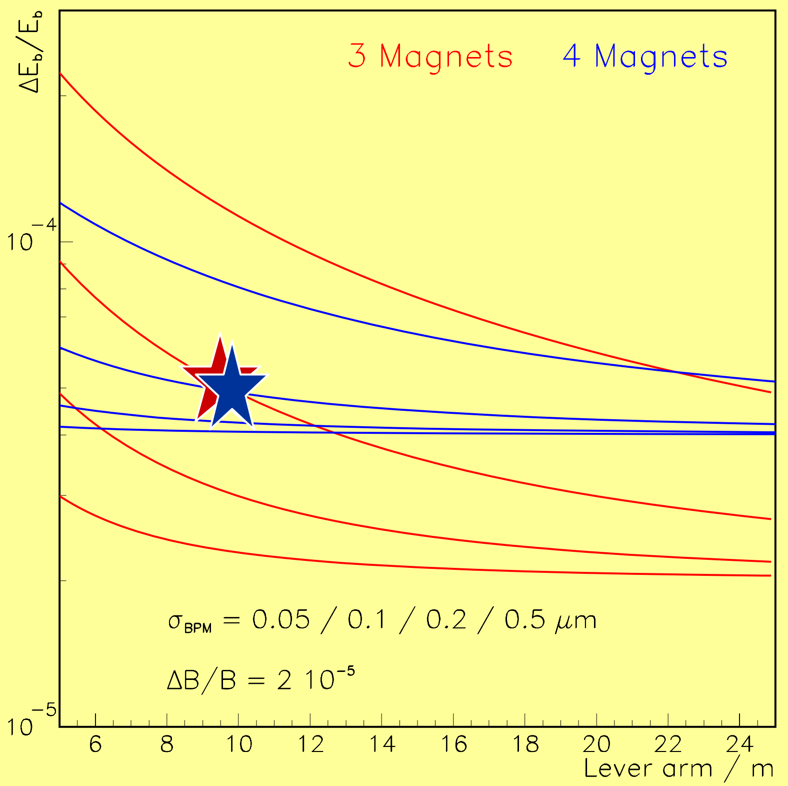


Error of X_0 measurement taken into account – same error as position measurement by the middle BPM triplet

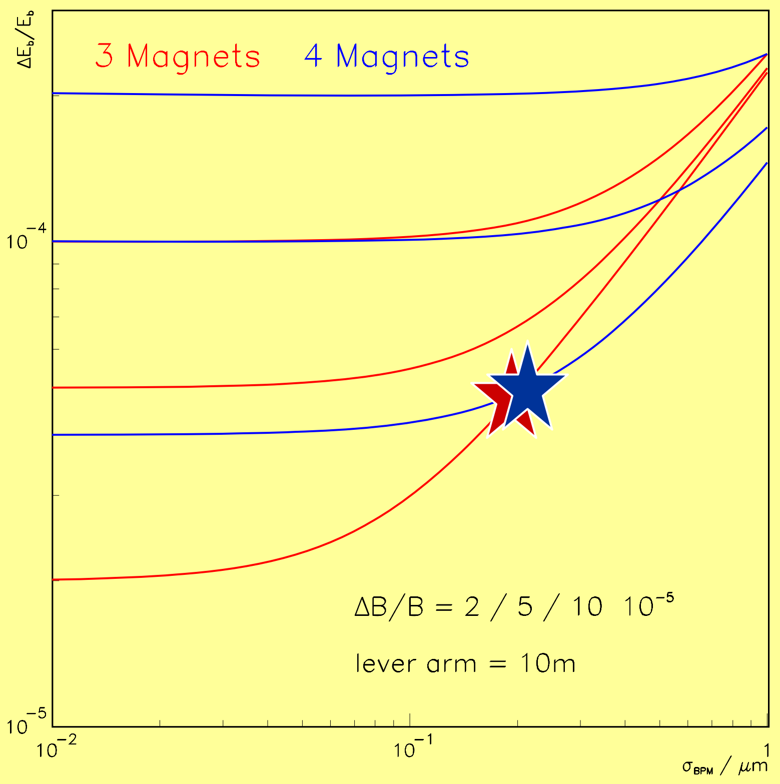
→ E-resolution plots will not be influenced (strongly)

Comparison 3 versus 4 magnets (1)

E-Resolution vs Distance of Magnets



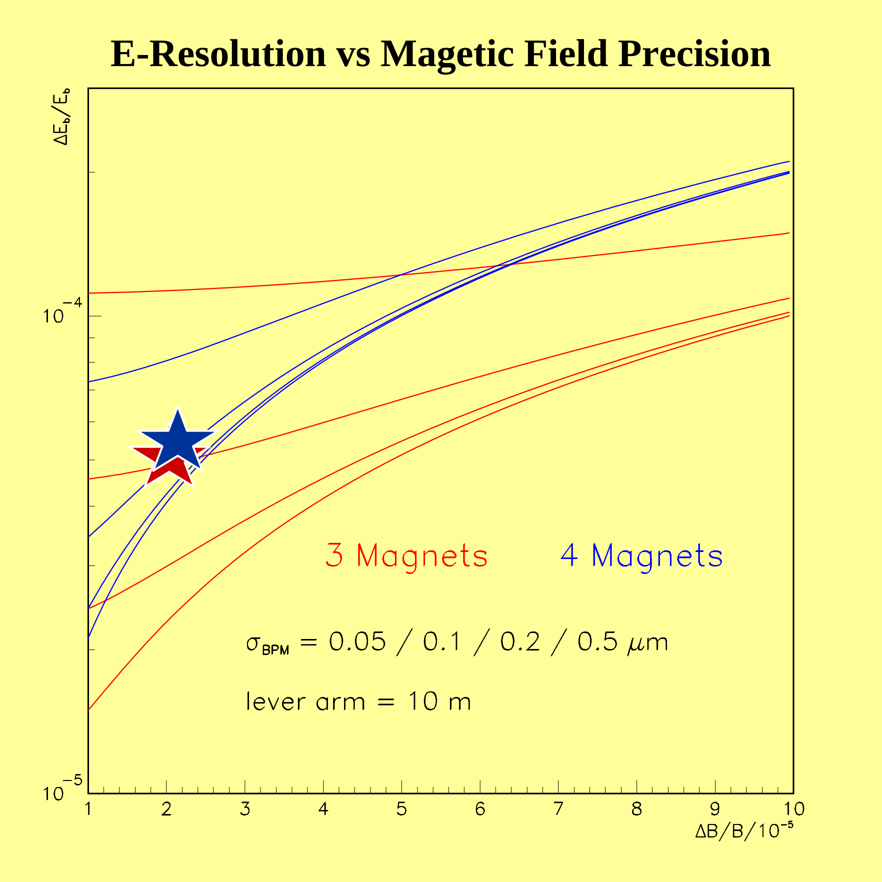
E-Resolution vs BPM Resolution

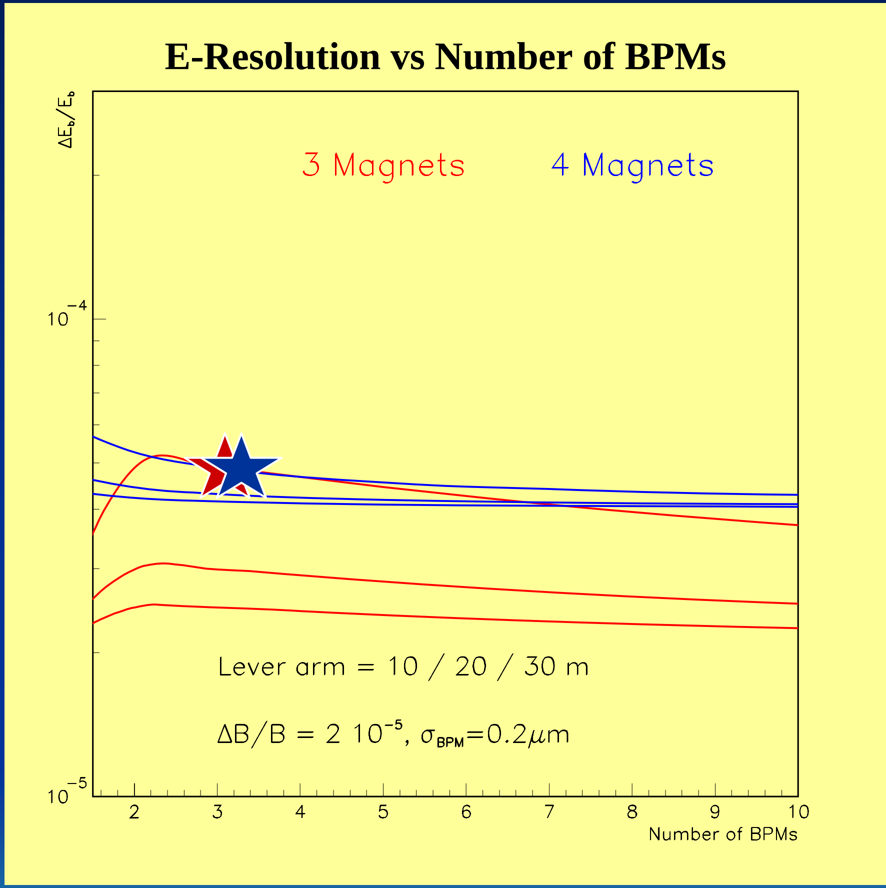


→ **for standard settings very similar E-resolution**

→ **3 magnets better with larger lever arm or smaller BPM resolution**

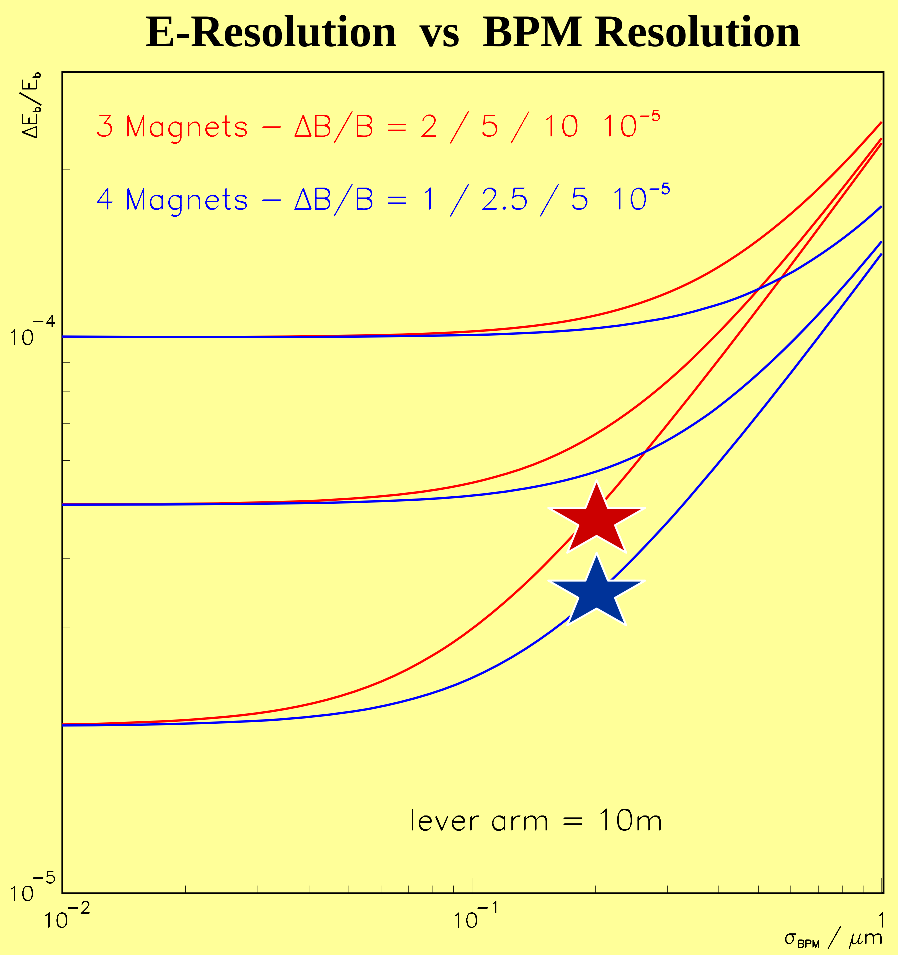
Comparison 3 versus 4 magnets (2)





→ **again same E-resolution for standard setting**
→ **3 magnets better in case of worse field precision**
→ **dependence on # BPMs small and similar**

Comparison 3 versus 4 magnets (3)



Assume factor 2 smaller field integral error for 4-magnet-version …

… same E-resolution as 3-magnet-version in case of asymptotic BPM-resolution

Summary

- for spectrometer “standard” settings *) the E-resolution of both versions is very similar ~ 5 x 10-5
- for improved BPM resolution and/or longer lever arm 3-magnet version is better
- for worse magnet field precision 4-magnet-version suffers more
- no strong dependence on # BPMs,
  (redundancy requests 2 x 4 or 3 x 3 BPMs)
- costs are in favor of 3-magnet-version since only 1 high precision magnet is needed instead of 4

*) ΔBl = 2 10-5, L = 10 m, Δx = 200nm, 2 x 3..4 BPMs