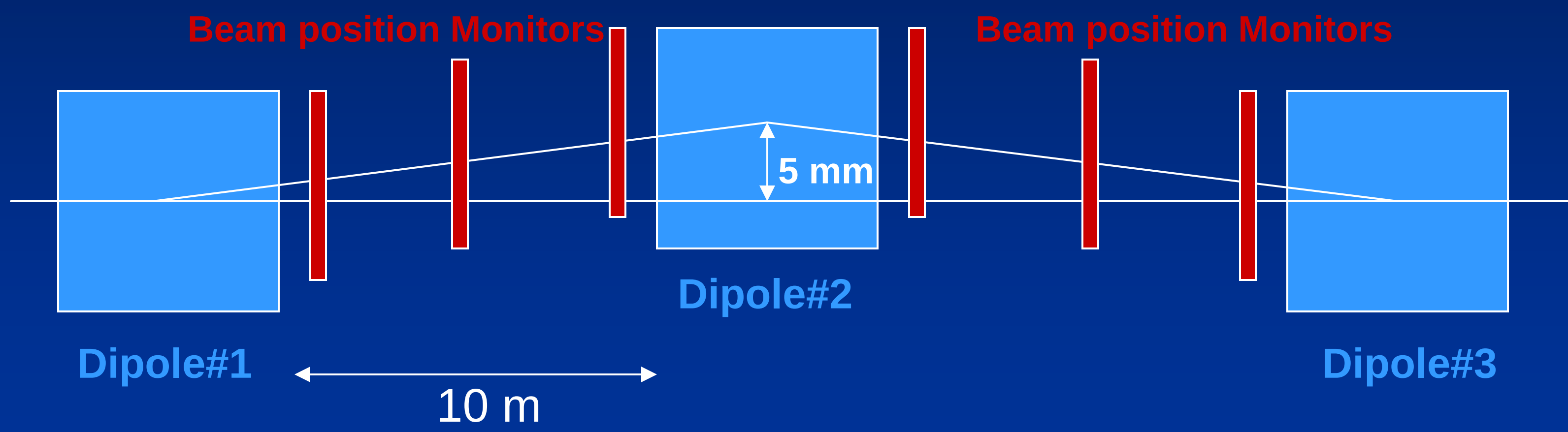
E-Measurement by Synchrotron Radiation

(some rough ideas)

K.Hiller, DESY Zeuthen on the Yerevan Meeting 2005

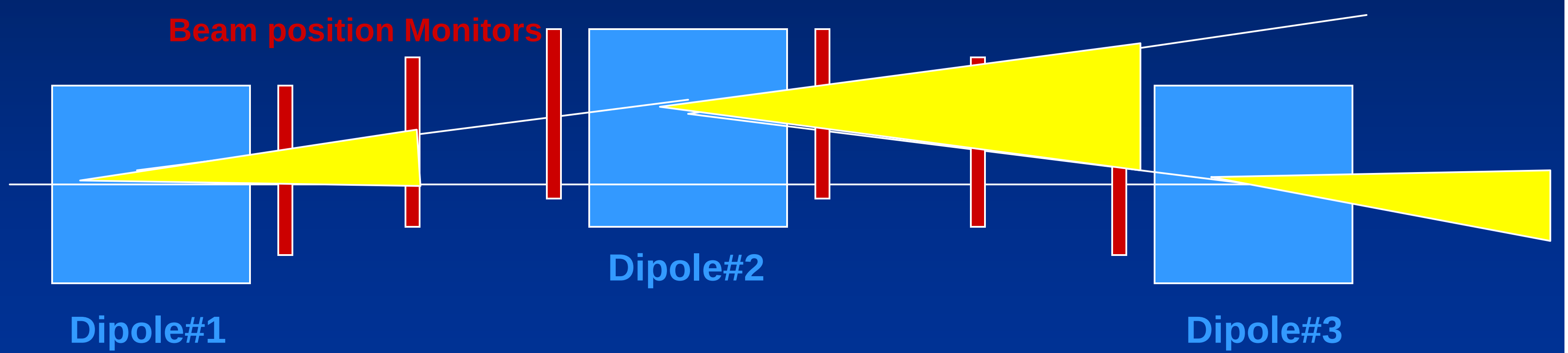
Basic Energy Spectrometer



E= 250 GeV, Bl = 0.4 Tm, σ_{BPM} = 200 nm → dE/E ~ 5 x 10^{-5}

E – measurement is based on precise angular measurement

Synchrotron Radiation Fan



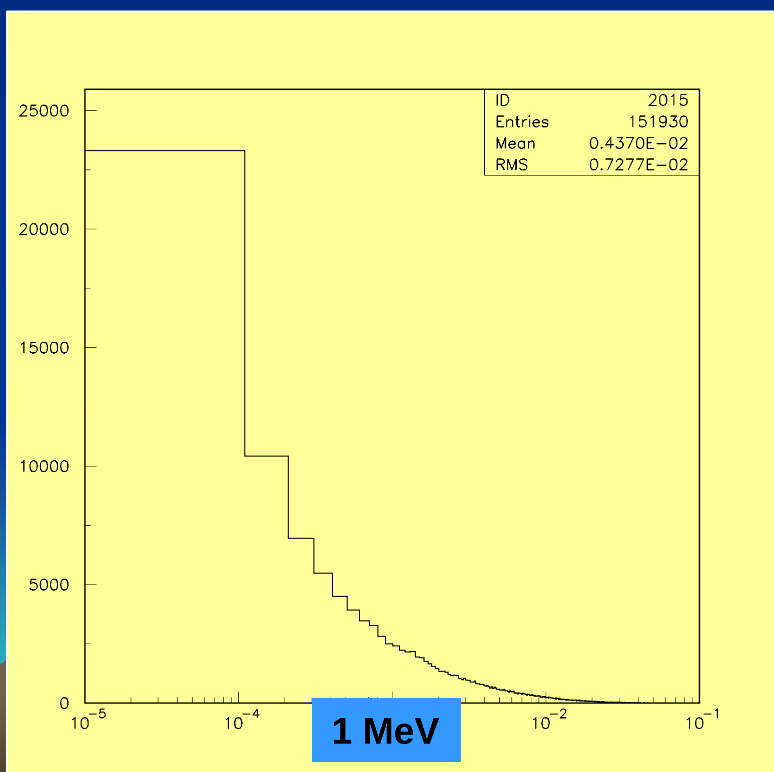
3 radiation fans cover exactly the electron bending angle
→ Measurement of fan edges determine electron energy

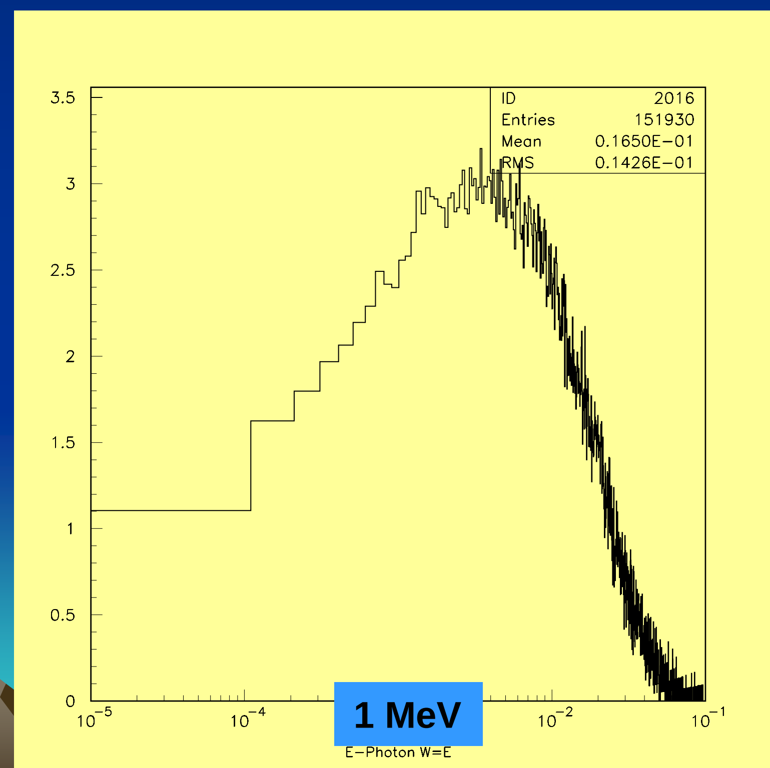
Synchrotron Radiation Spectrum

Critical energy:
50% of power

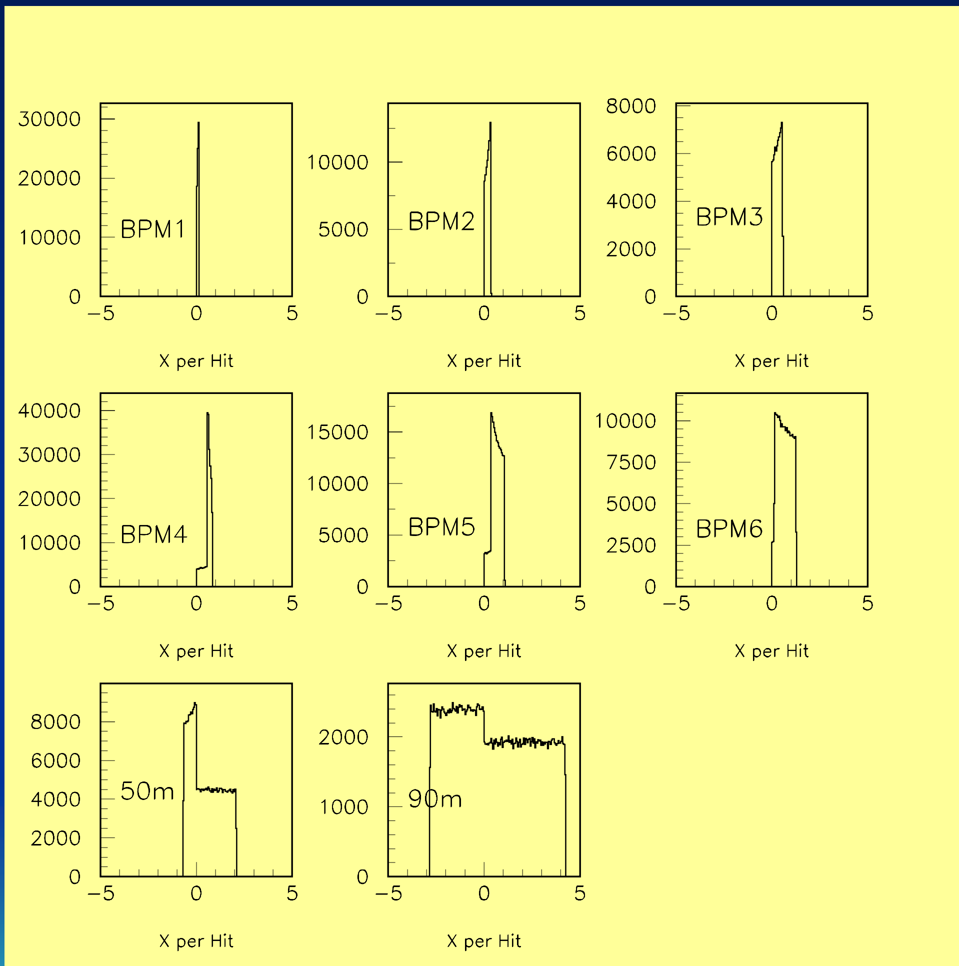
$$E_{crit}[keV] = 0.665 \cdot B[T] \cdot E^2[GeV]$$

250 GeV, 0.5 mrad or 0.4 Tm → E_{crit}= 16.6 MeV





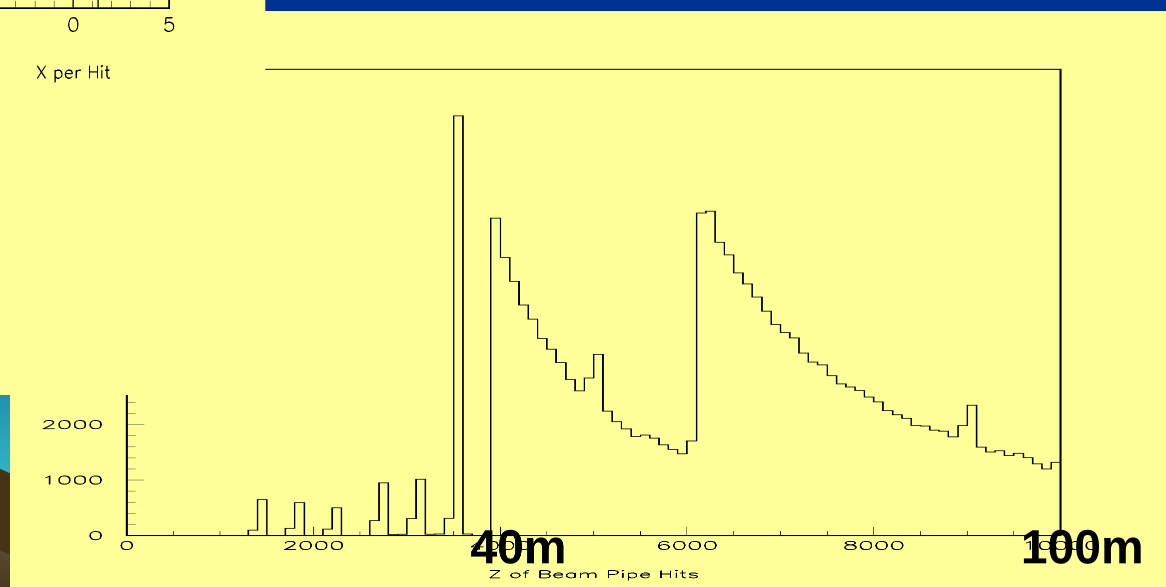
Radiation Fan along the Beam



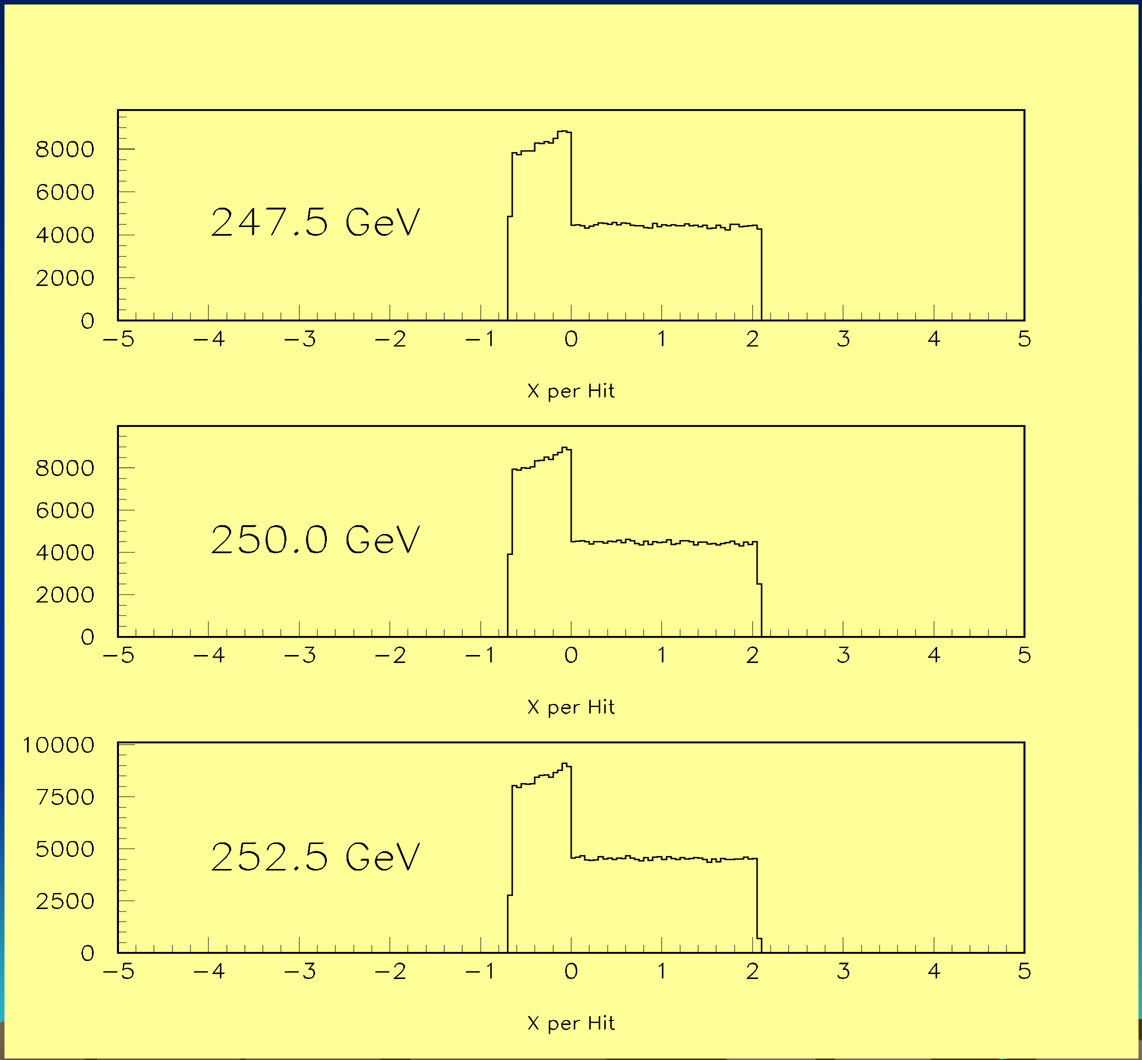
Beam tube R = 10 mm
Thickness 2 mm steel

→Radiation fan at BPM positions inside tube

→Touch the steel walls downstreams of ~ 40m



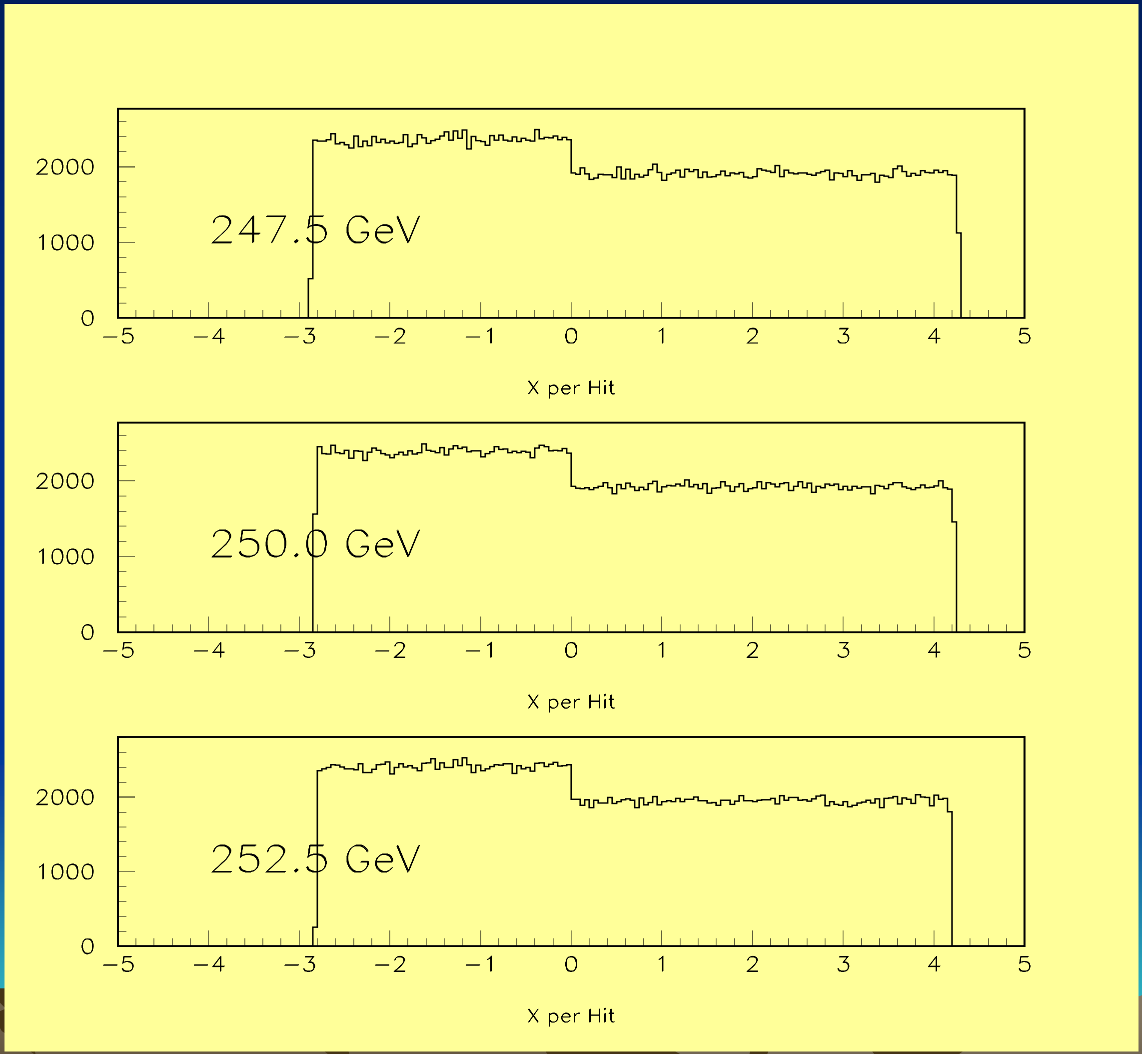
Radiation Fan at 50 m



Most photons still
Inside the beam tube

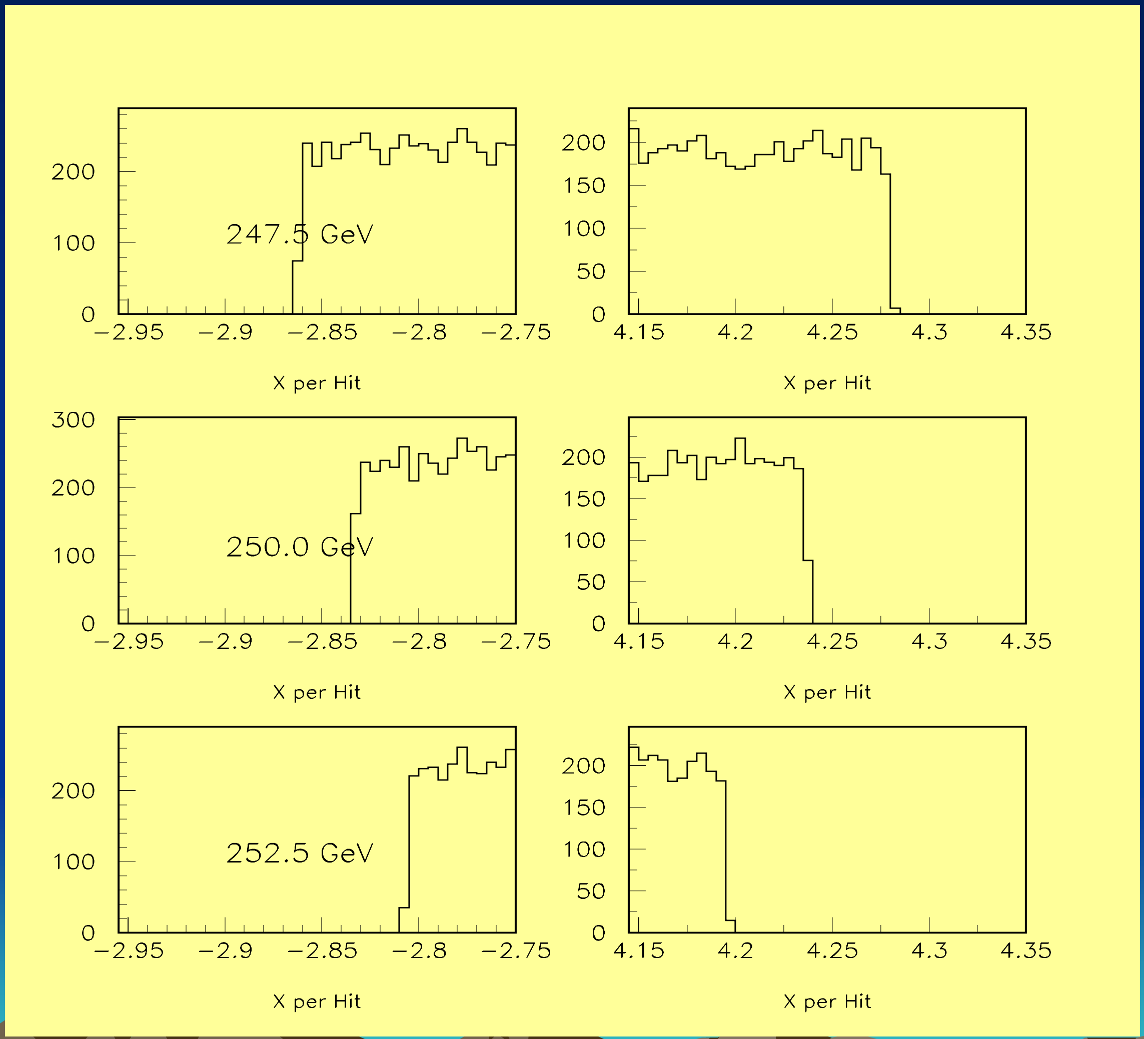
Especially left edge
Not visible !

Radiation Fan at 90m



Both edges visible outside the beam tube

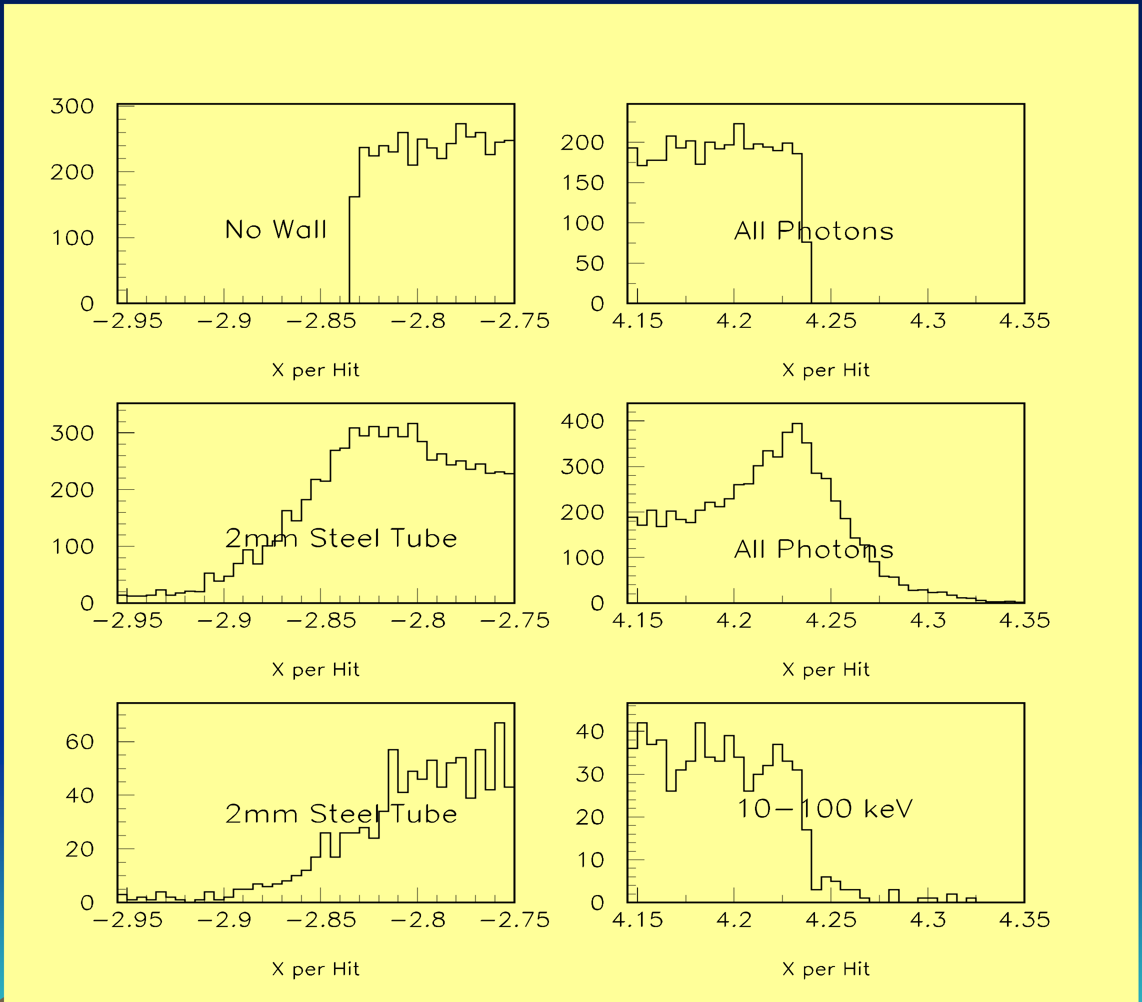
Radiation Fan at 90m (2)



E/GeV	Width/mm
247.5	71.4
252.5	70.0

→ Sensitivity
1.4 mm / 5 GeV

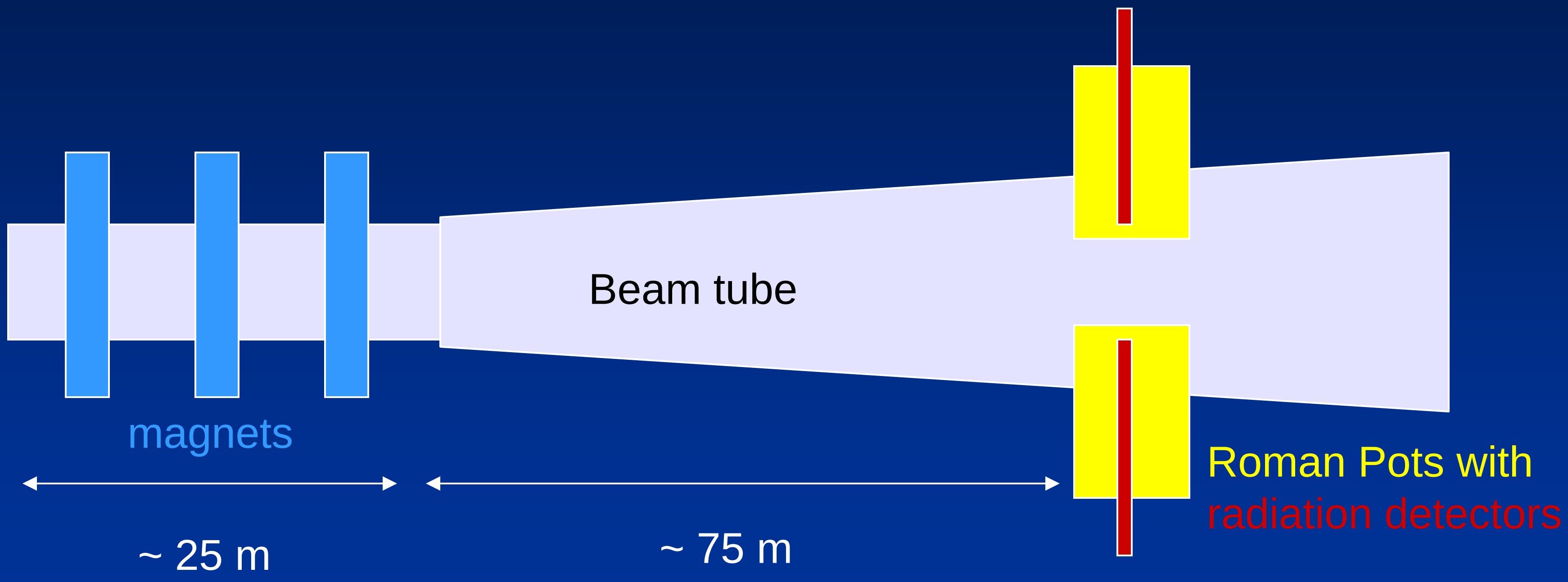
The Influence of the Walls



2 mm steel tube deteriorates resolution

Selection of 10 -100 keV photons changes not much

Basic Detector Layout



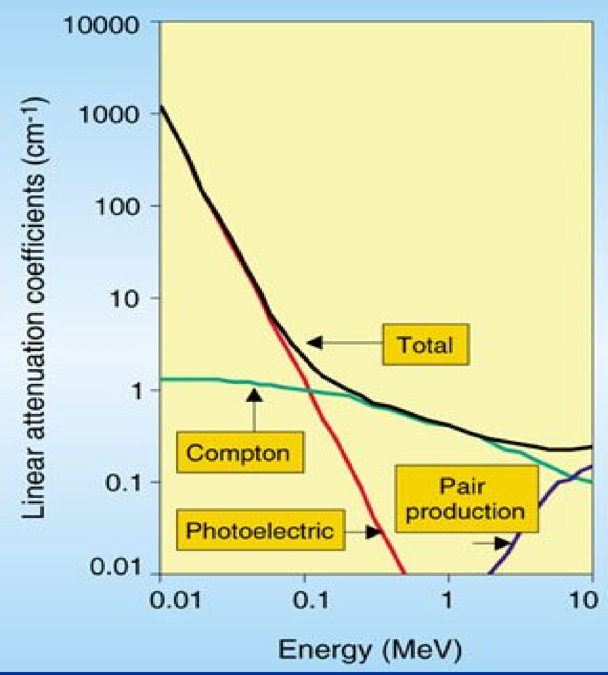
- Enlarge tube diameter R = 1cm → 4cm
- Install 2 Roman pots with thin ~ 300 μm steel windows
- Insert position sensitive radiation detectors

Detection of X-Rays

X-rays have no electric charge and cannot directly detected:

→1) use scintillators to get low energetic photons of 200 – 1000 nm which match sensitivity of PMT or photodiode

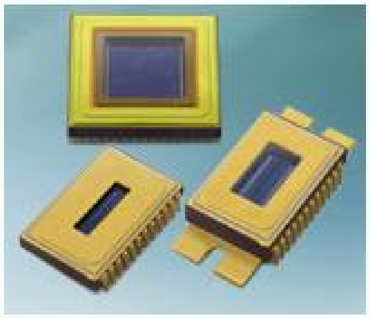
→2) convert X-rays into electrons/positrons which produce electron-hole pairs by Coulomb interaction, and collect their charge



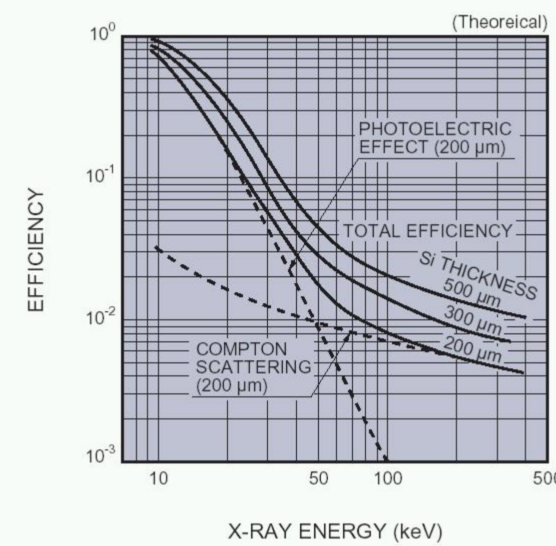
	Photoelectric	Compton	Pair Production
interacts with	bound electron	"free" electron	atomic nucleus
energy range	<100 keV	~100 keV - 10 MeV	>1.02 MeV (pred >10 MeV
energy variation	$1/E^3$	1/E	E
Z variation	$\sim Z^3$	none	Z

Hamamatsu CCD

CCD

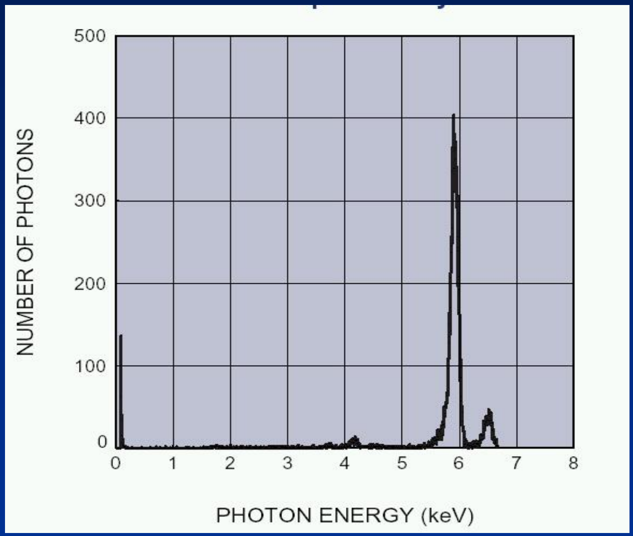


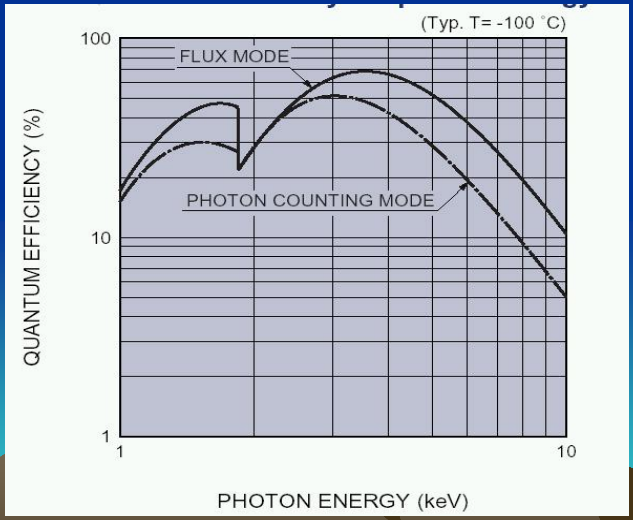
Charged-Coupled Devices (CCDs) are solid-state image sensors that provide low light level detection, with high signal-to-noise ratio and wide dynamic range. The vast majority of our CCDs are full frame transfer devices with 100% fill factor. We offer scientific grade CCDs including a unique back-thinned (BT-CCD) device featuring 90% quantum efficiency (QE). The back-thinned CCD has high QE from the near infrared to the vacuum UV region of the spectrum and it can even directly detect X-rays with energy below 0.5 keV. Front-illuminated CCDs can be used to directly detect X-rays up to 10 keV and X-rays over 100 keV can be imaged using fiber optic scintillators (FOS). Our CCD detectors are used in low light level imaging, raman spectroscopy, microscopy, non-destructive inspection, dental X-ray imaging and medical imaging.

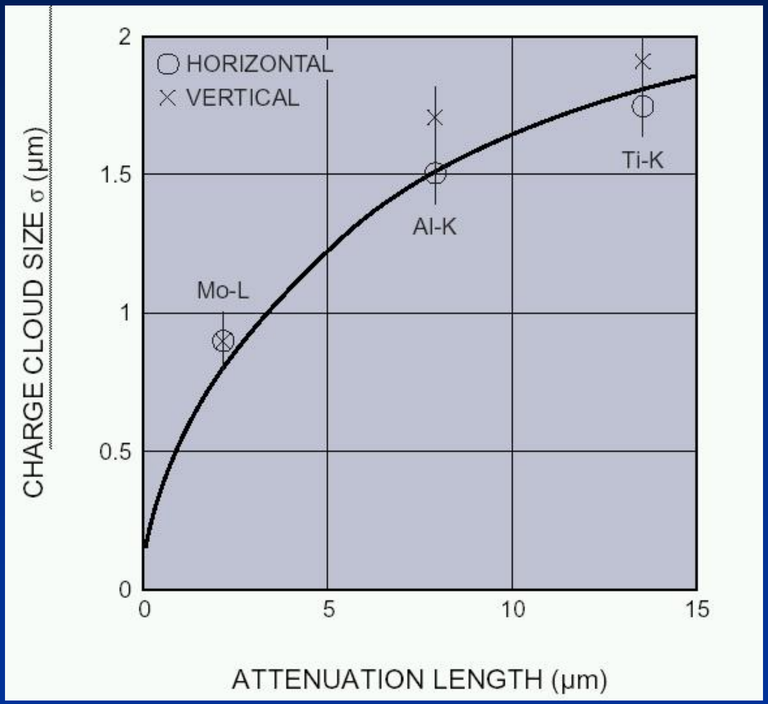


→ CCDs or other (thin) solid state detectors measure in the range < 100 keV

CCD Characteristics







- dE = 109 eV at 5.9 keV (Fe55)
- quantum efficiency > 10% at E < 10 keV
- 12 x 12 μm2 plus micro-mesh plate gives 1 … 2 μm spatial resolution
- drawback - slow readout in msec

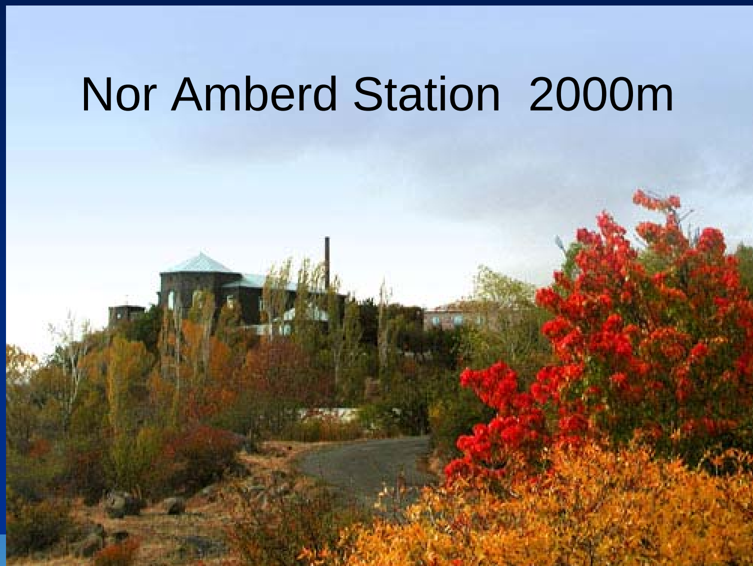
Conclusions

- **Energy resolution : spatial resolution / sensitivity**

dX	dE	dE / E	Feasibility
100 μm	357 MeV	1.4 10^{-3}	→ possible with existing detectors
10 μm	36 MeV	1.4 10^{-4}	→ in reach with some detector R&D
1 μm	4 Mev	1.4 10^{-5}	→ probably a dream

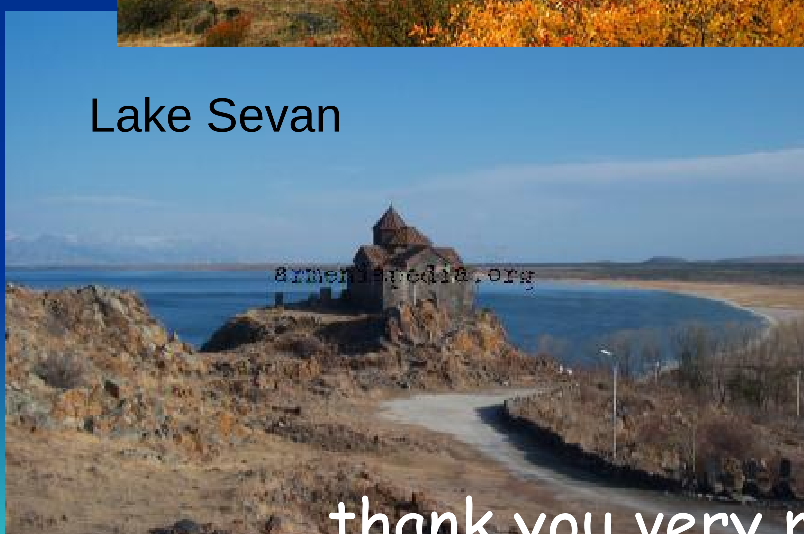
- **needs some 100m dedicated beam line free of magnets**
- **simple scheme using well-proven Roman Pot technology**
- **radiation detectors easy to exchange (radiation damage !)**
- **width of the radiation fan insensitive to changes of beam offsets and inclinations**
- **without calibration good for relative beam energy changes**

Acknowledgement

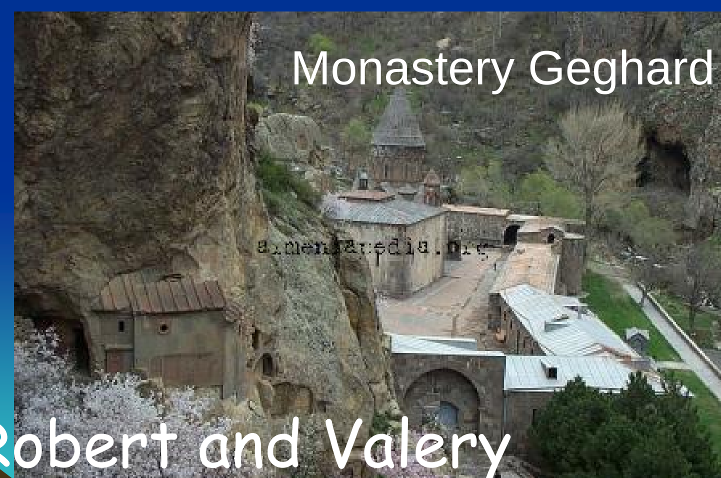


Nor Amberd Station 2000m

Aragats South Peak 4090m



Lake Sevan



Monastery Geghard

… thank you very much Robert and Valery
for the meeting in such great surroundings.