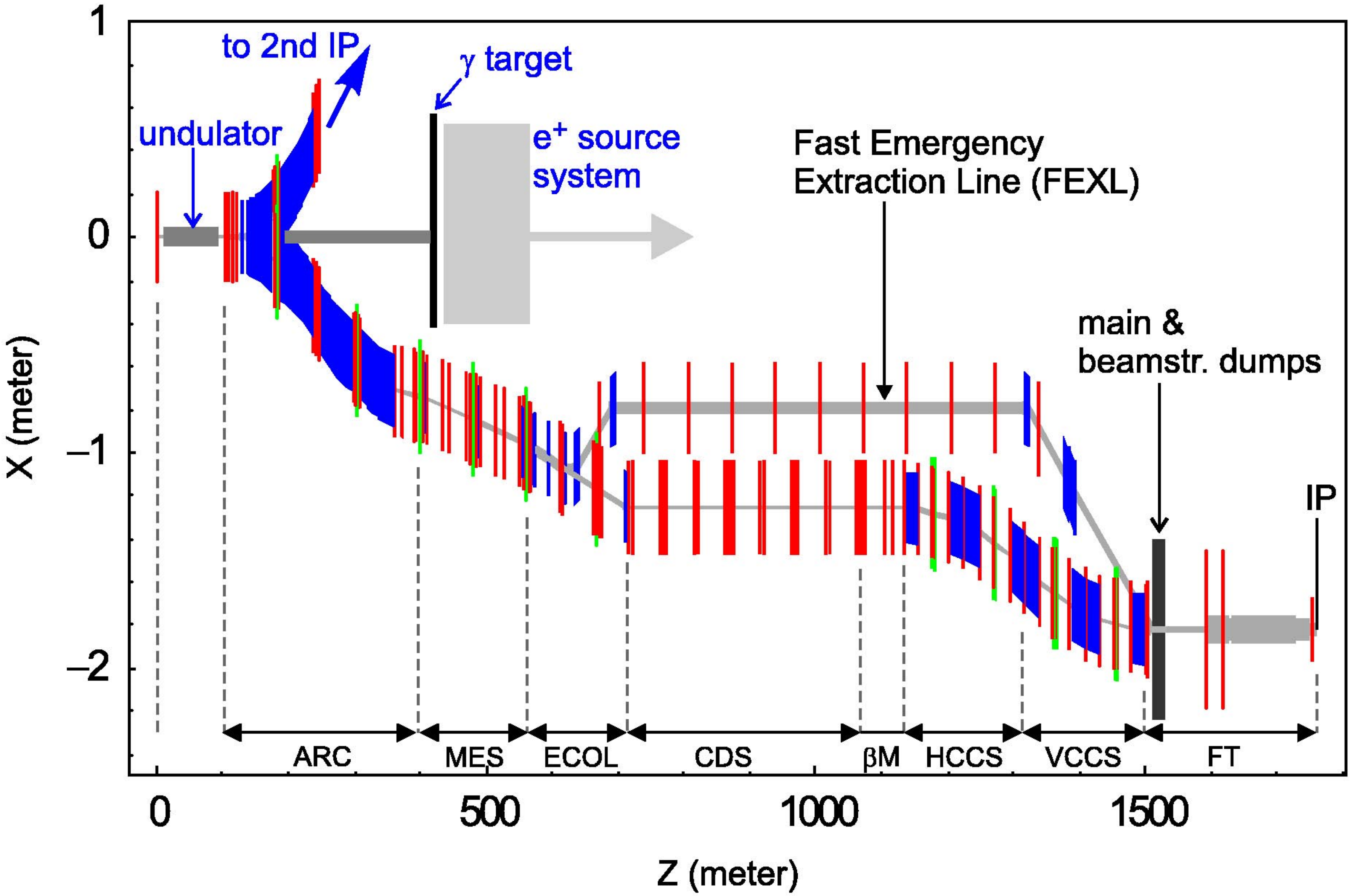
A Precision Spectrometer for the TESLA (TDR) Beam Delivery System

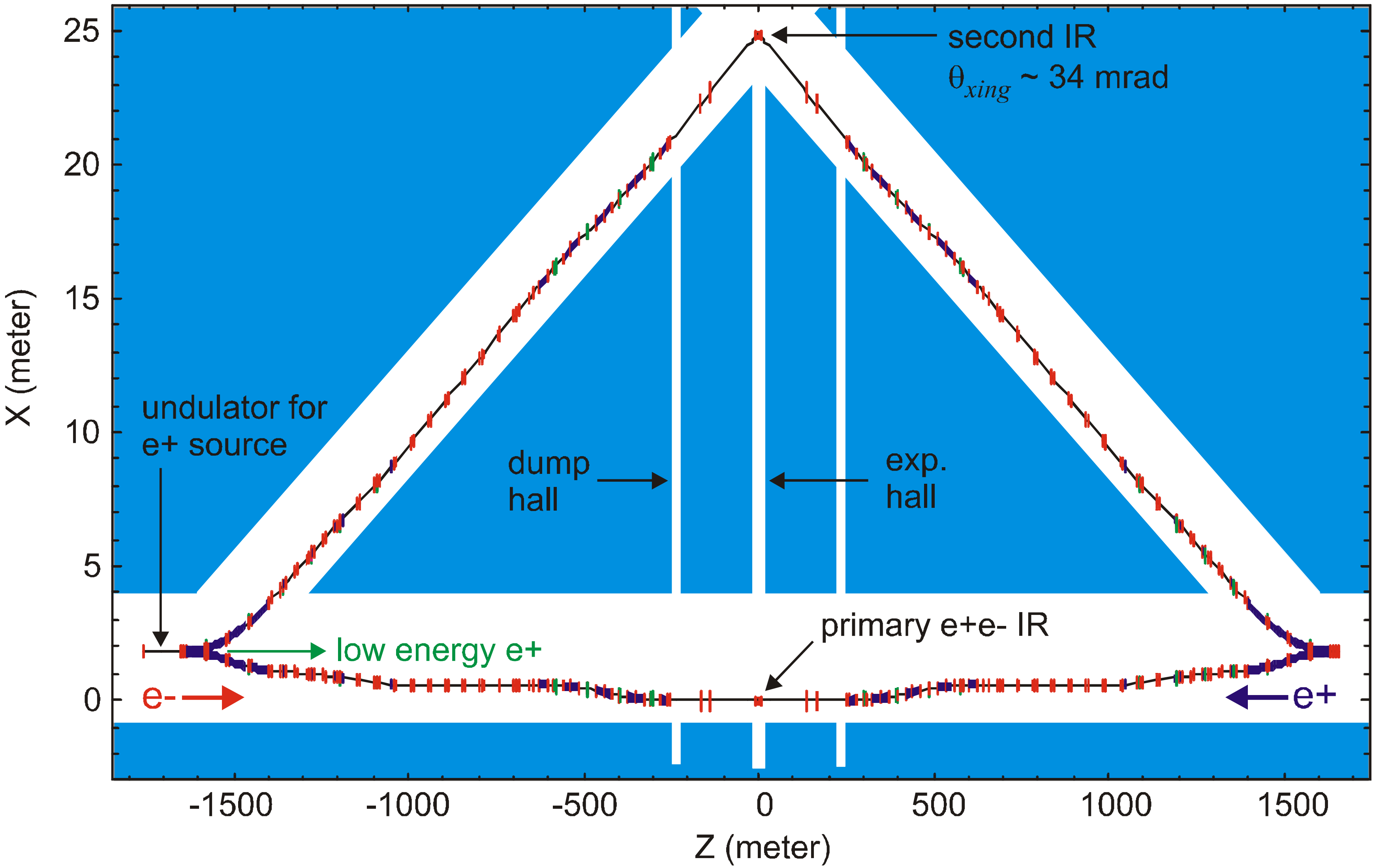
Nick Walker
DESY

BDS Layout

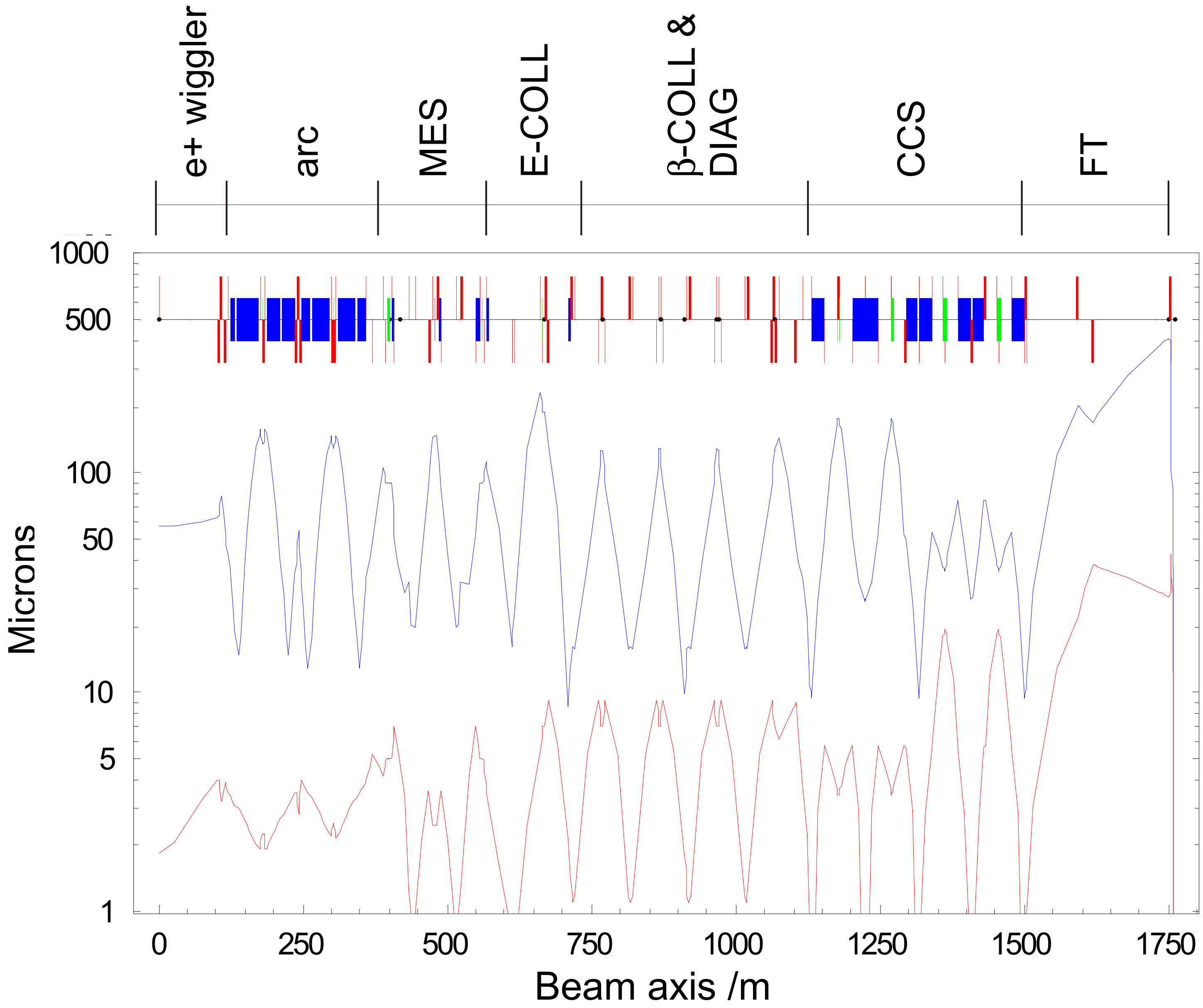


1
to 2nd IP
γ target
undulator
e+ source
system
Fast Emergency
Extraction Line (FEXL)
0
main &
beamstr. dumps
X (meter)
–1
IP
–2
ARC
MES
ECOL
CDS
βM
HCCS
VCCS
FT
0
500
1000
1500
Z (meter)

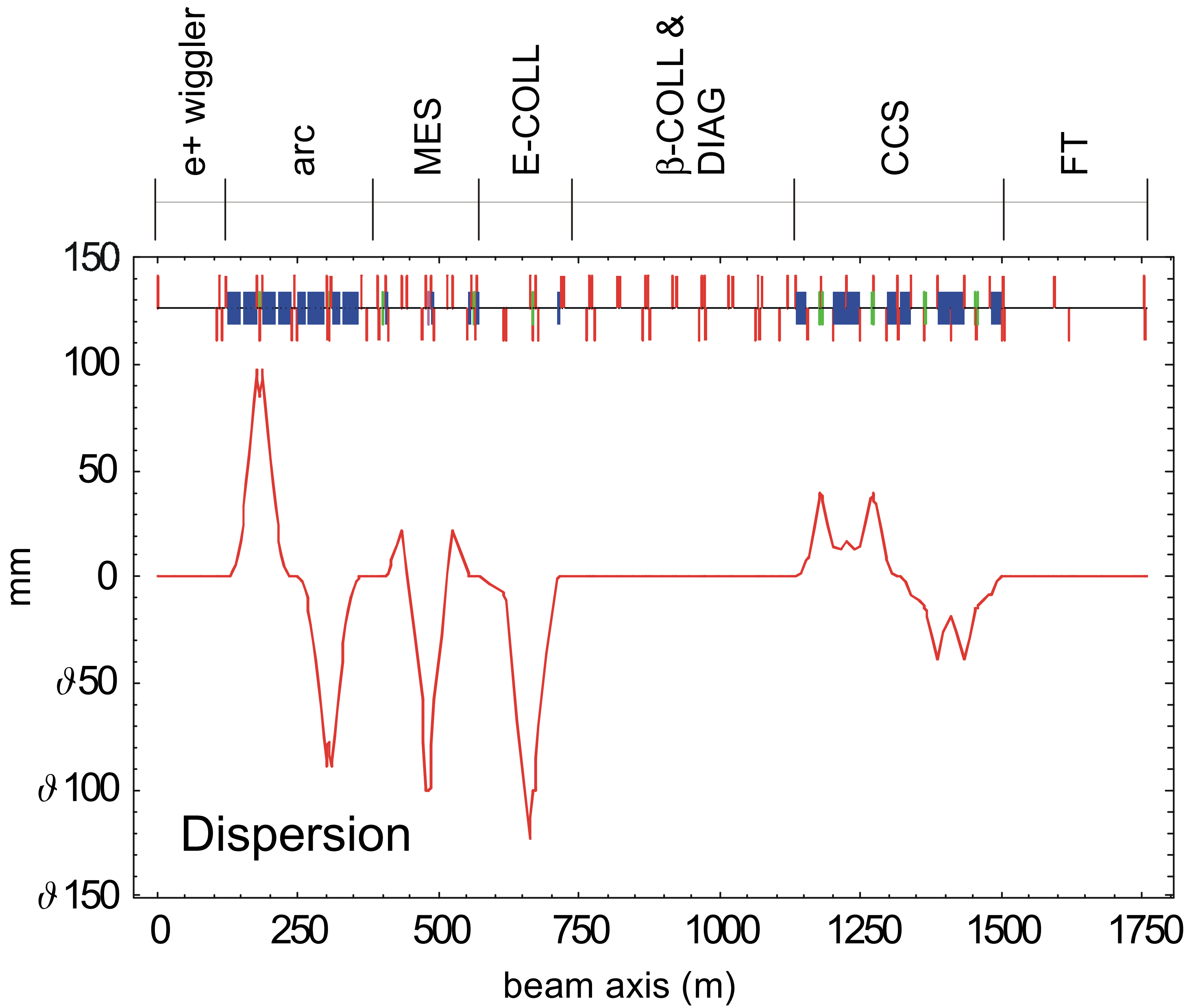
Second IR Geometry



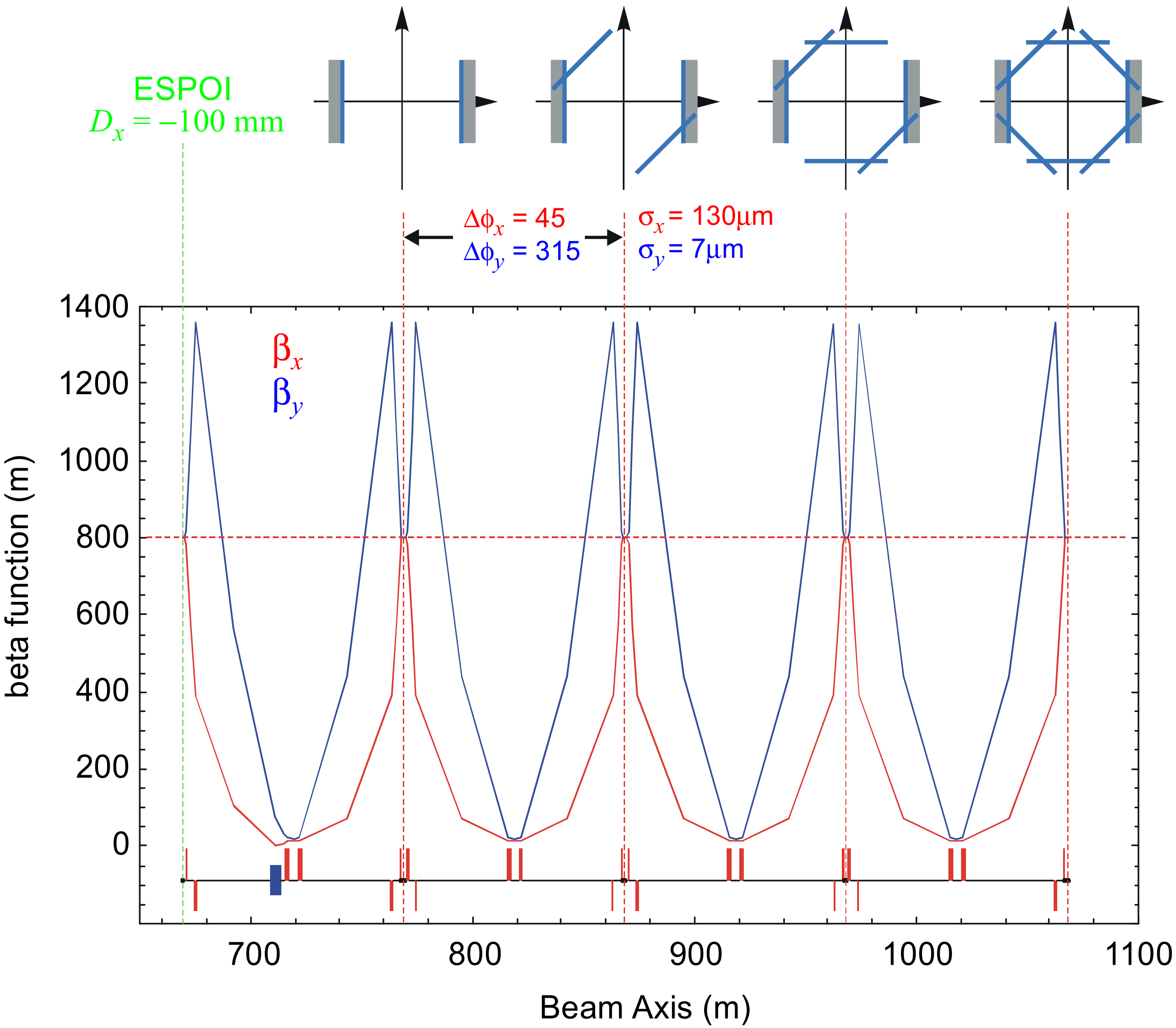
Lattice (Beam Envelope)



Lattice (Dispersion)



Diagnostics & Collimation System



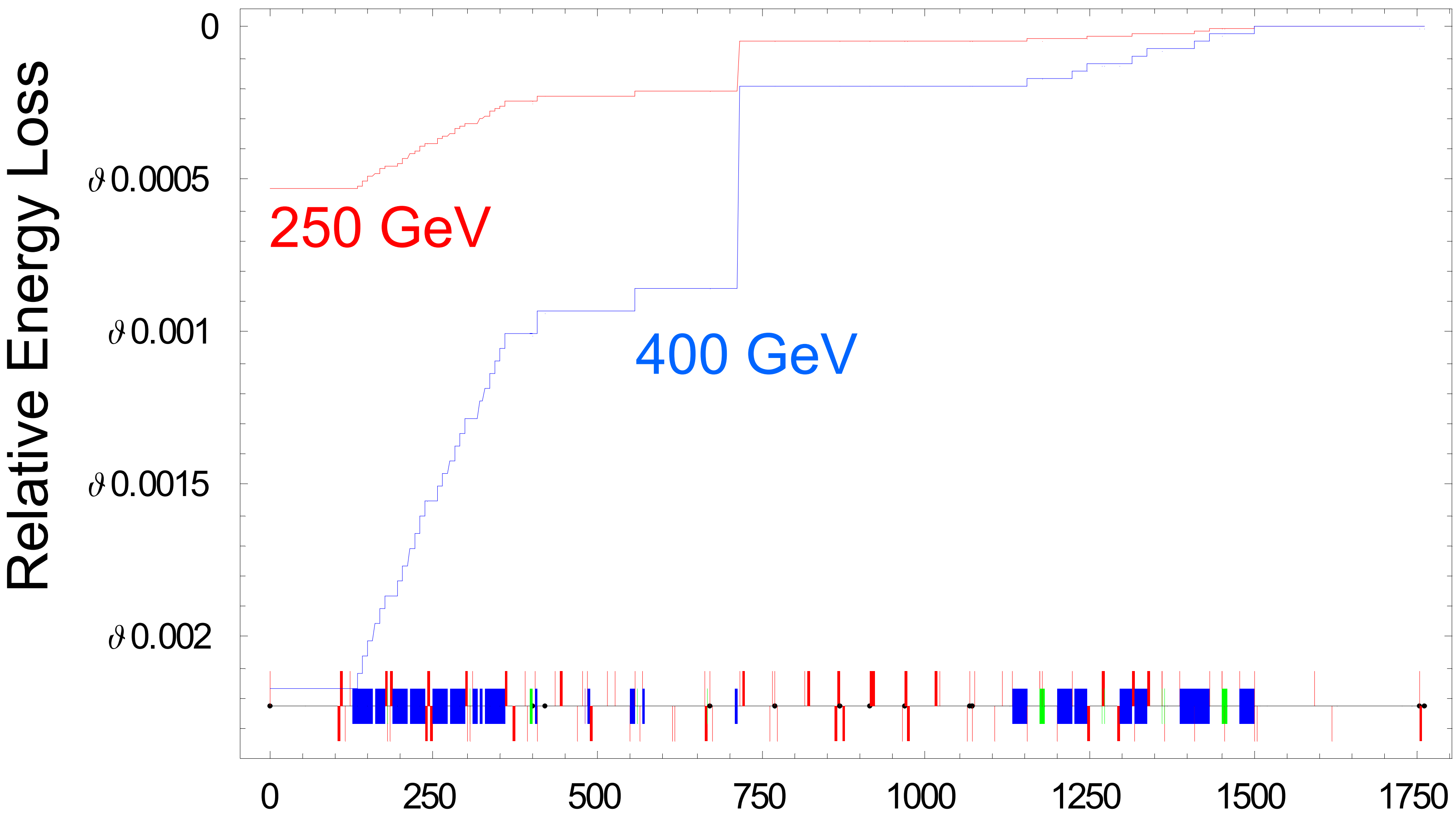
$\sigma_{x/y}$ = 130 / 7 µm

$\Sigma_{x/y}/\sigma_{x/y}$ = 13 / 80

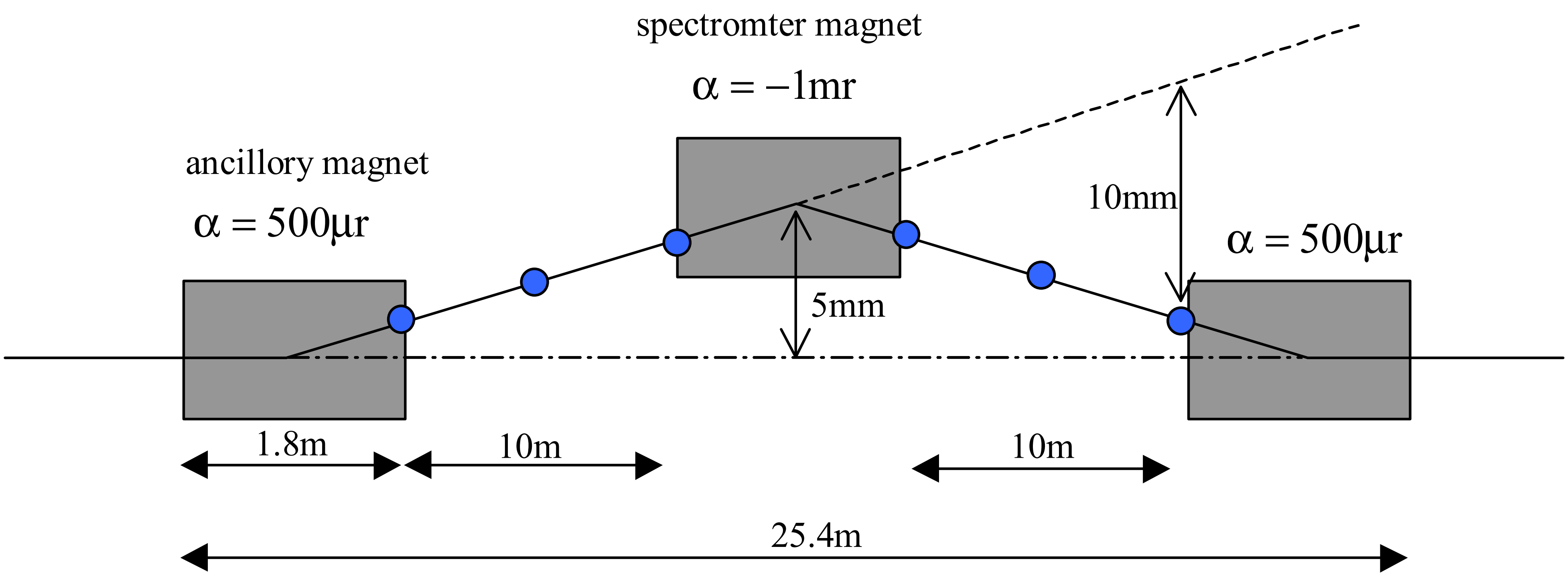
$a_{x/y}$ = 1.5 / 0.5 mm

Free space
~35m

Synchrotron Radiation

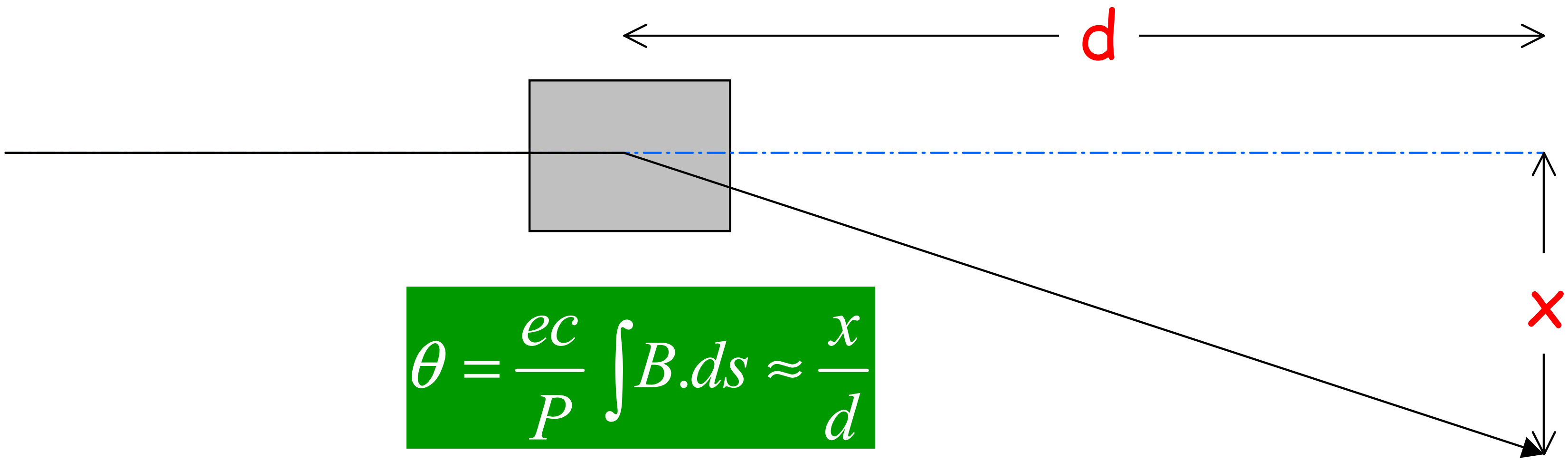


Chicane Spectrometer



BPM resolution	Energy Resolution
1 μm	few 10^{-4}
100 nm	few 10^{-5}

Chicane Spectrometer (basics)



$$\theta = \frac{ec}{P}\int B.ds \approx \frac{x}{d}$$

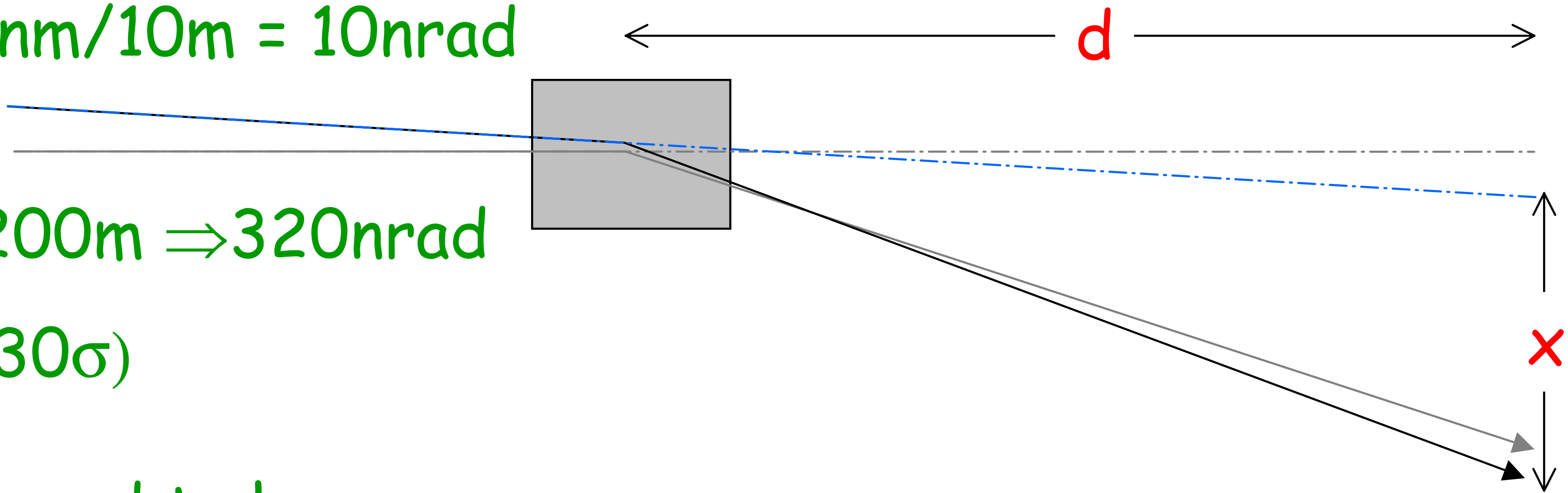
need to know

- x (100nm @ 10m, 1mrad)
- d (0.1mm @ 10m) use timing signal?
- field map $\int B.ds$

to a precision of 10^{-5}

Chicane Spectrometer (basics)

incoming angle:
100nm/10m = 10nrad



β=200m $\Rightarrow$320nrad

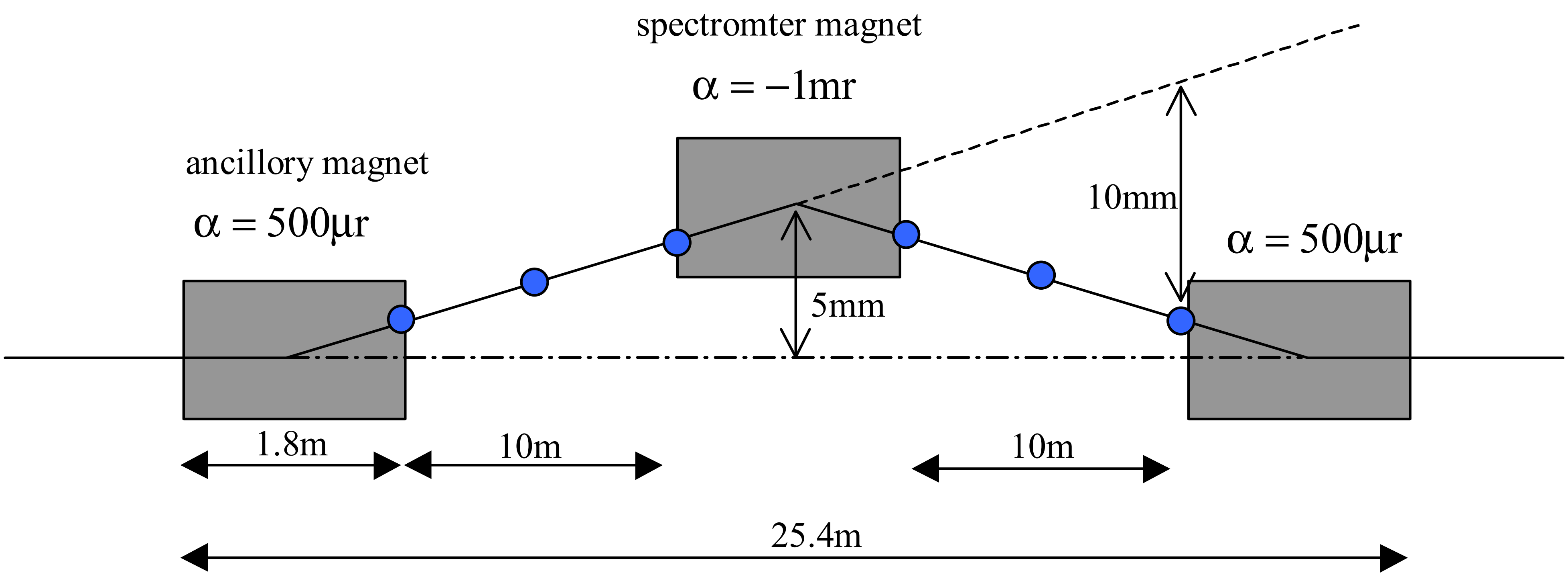
(1/30σ)

need to know

- x (100nm @ 10m, 1mrad)
- d (0.1mm @ 10m) mag. centre!
- field map $\int B.ds$

to a precision of 10^{-5}

Chicane Spectrometer



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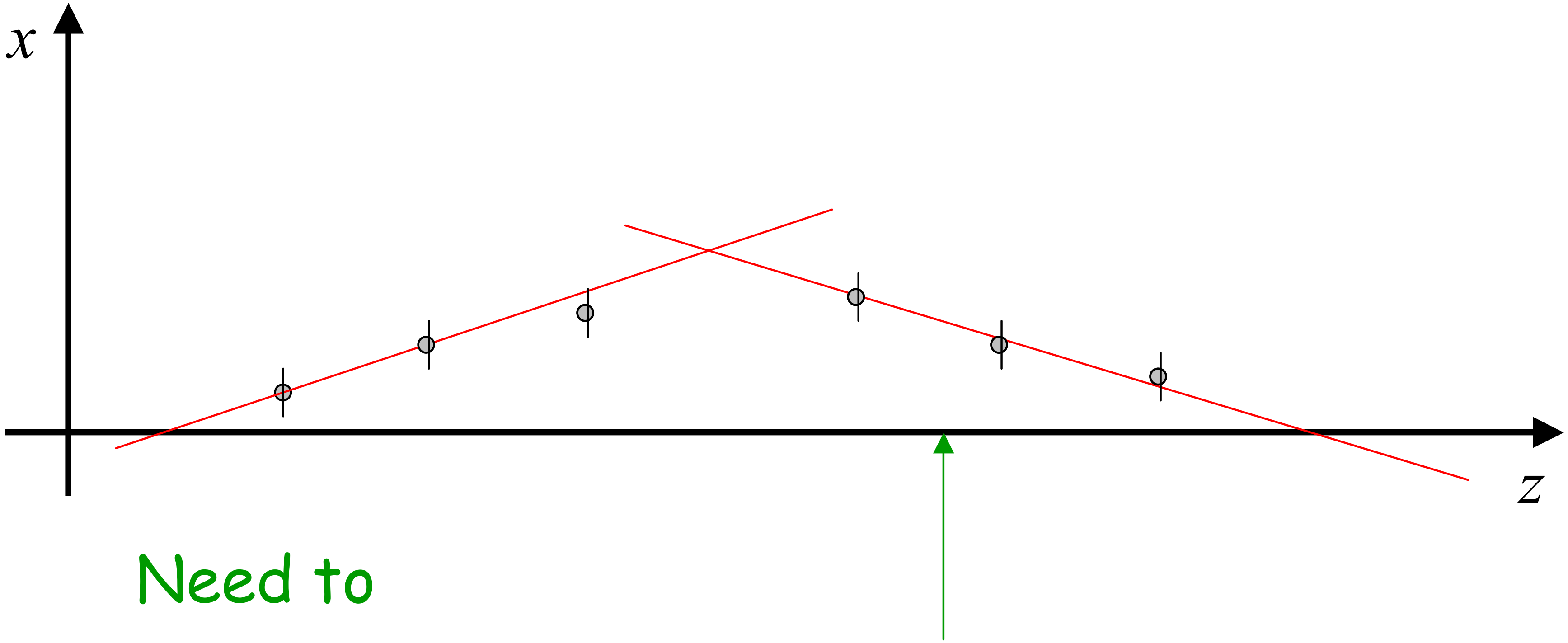
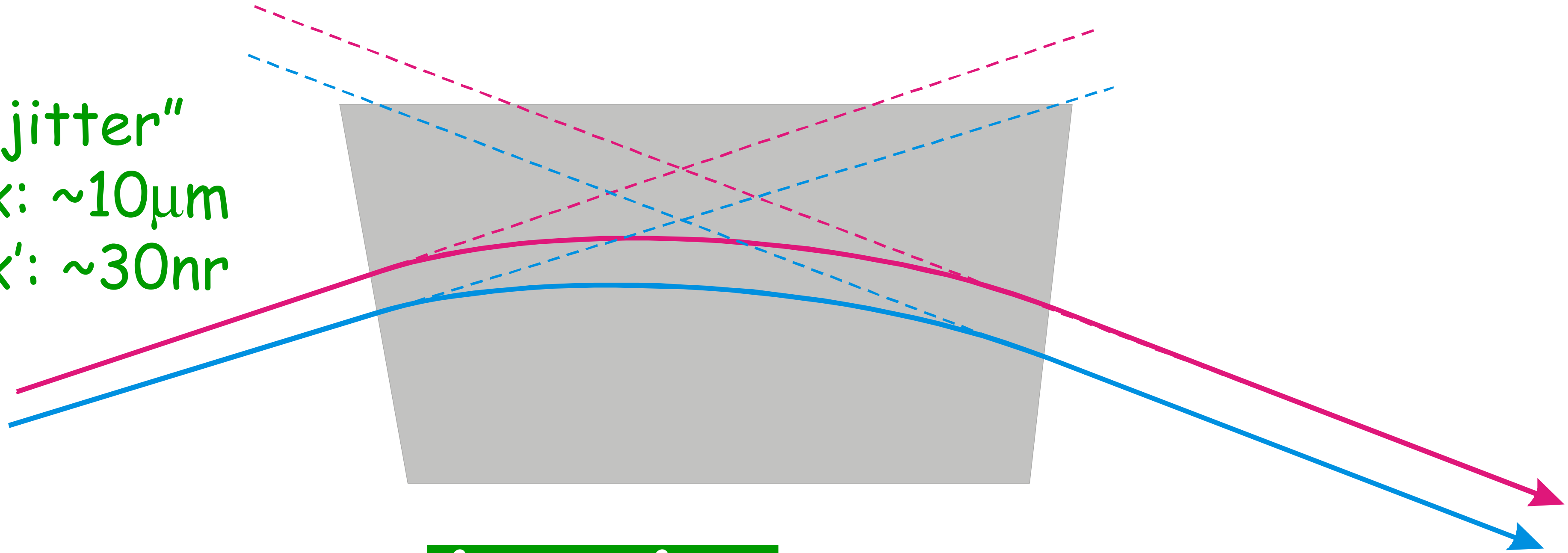


Need to

- accurately determine <u>baseline</u> (BPM offsets)
    - ballistic beam-based alignment
- BPM must 'measure' millimetres±100nm
    - mechanically move BPM centres?

Spectrometer Magnet

"jitter"
x: ~10μm
x': ~30nr



$$\int_1 B.ds \approx \int_2 B.ds$$ to better than 10^{-5}?

in general: $\theta = \theta(x, x', y, y', p)$

Spectrometer Magnet: Synchrotron Radiation

$$\Delta E \approx \frac{8.85\times10^{-5}[\mathrm{GeV}^{-3}\mathrm{m}]}{2\pi}\frac{E^4 L}{\rho^2}$$

- Take 1.8m magnet with 1 mr angle
  - ΔE_{250} ~ 30 MeV (10^{-4}, <P>~1 kW)
  - ΔE_{400} ~ 200 MeV (5×10^{-4}, <P>~9 kW)
- Would like to reduce this to 10^{-5}
  - reduce angle by factor 3 (BPM res. also)
  - increase length by factor 10!!
- Live with loss and compensate in measurement (average power is quite high!)

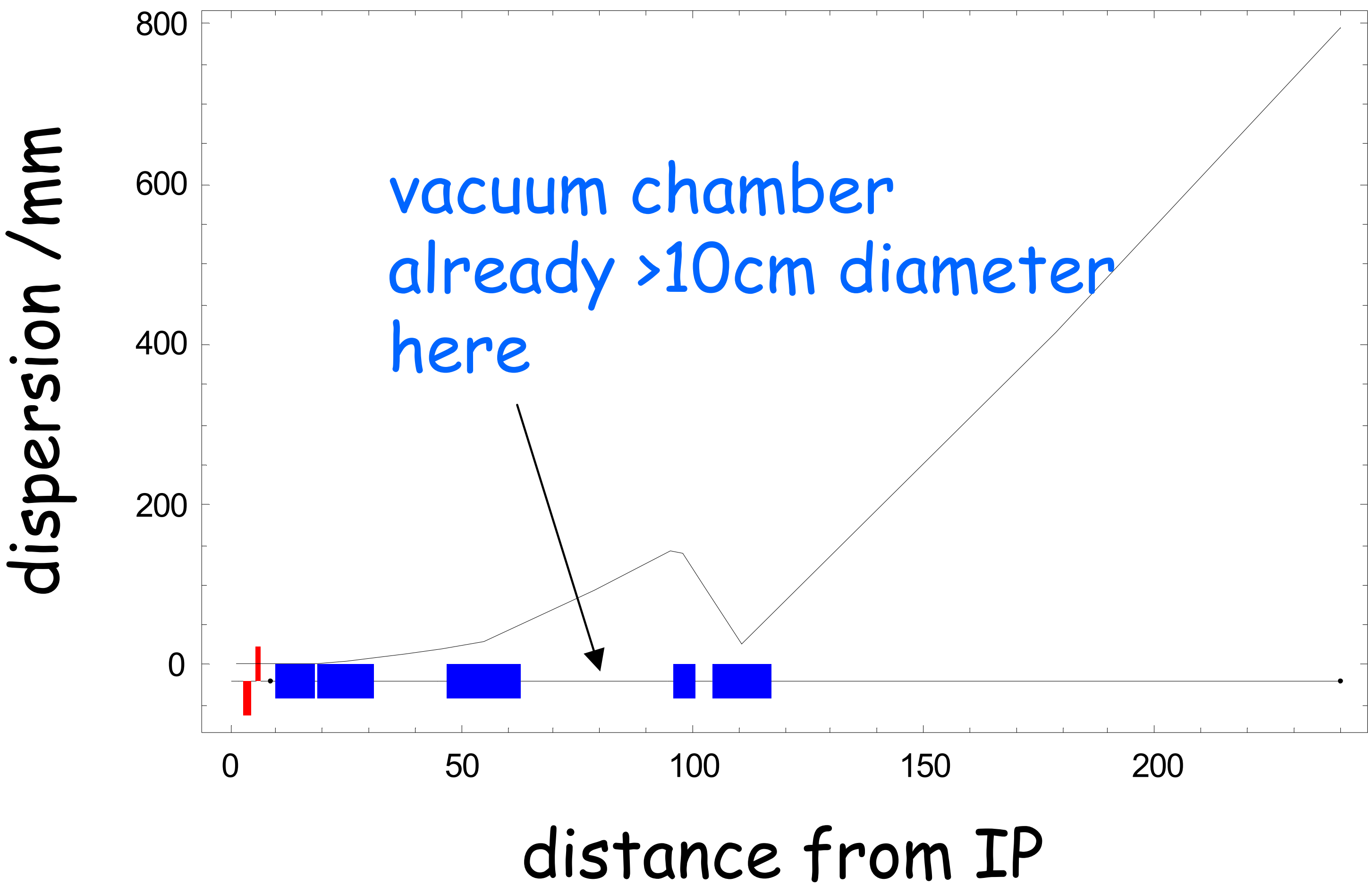
Stability

- At 10^{-5} level, will need to calibrate against known energy (Z-pole?)
- How long before spectrometer drifts?
  - BPM drift (electronic, ground motion)
  - magnet drift
  - beam trajectory (magnet) drift (ground motion, tuning, feedback etc.)
- For GM make estimate using ATL law (σ^2=ATL):
  - $\Delta T \sim (100\text{nm})^2 / 4\times10^{-6}\ \mu\text{m}^2\text{m}^{-1}\text{s}^{-1} / 10\text{m} \approx 250\ \text{s}$

Stability (cont.)

- Construct spectrometer on single girder
  - 20+ meter structure!
  - mechanical stability (thermal effects)
- Still need to worry about
  - BPM electronic drift (bigger worry?)
  - Spectrometer magnet stability?

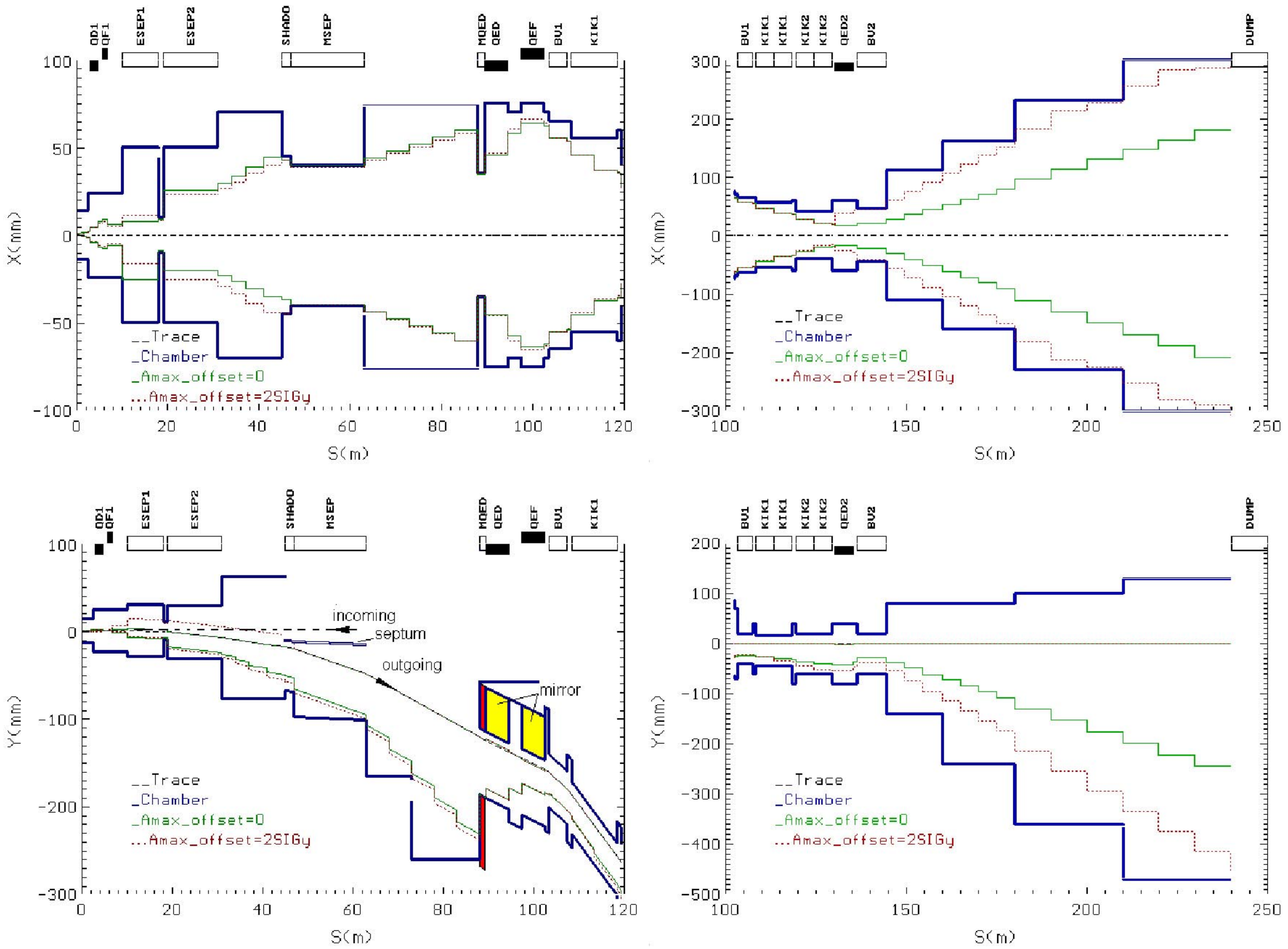
Extraction line: Vertical Dispersion



Spent beam extraction

horizontal

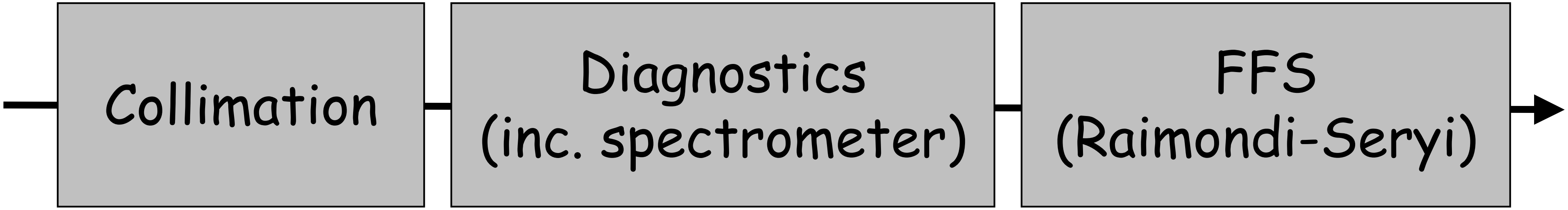
vertical



0-120 m

100-250 m

A New BDS System for TESLA



Dedicated lattice for diagnostics:

- emittance measurement
- polarimeter
- spectrometer
- other (bunch length?)