SFB/TR16

Precision Compton Polarimetry using a counting silicon microstrip detector

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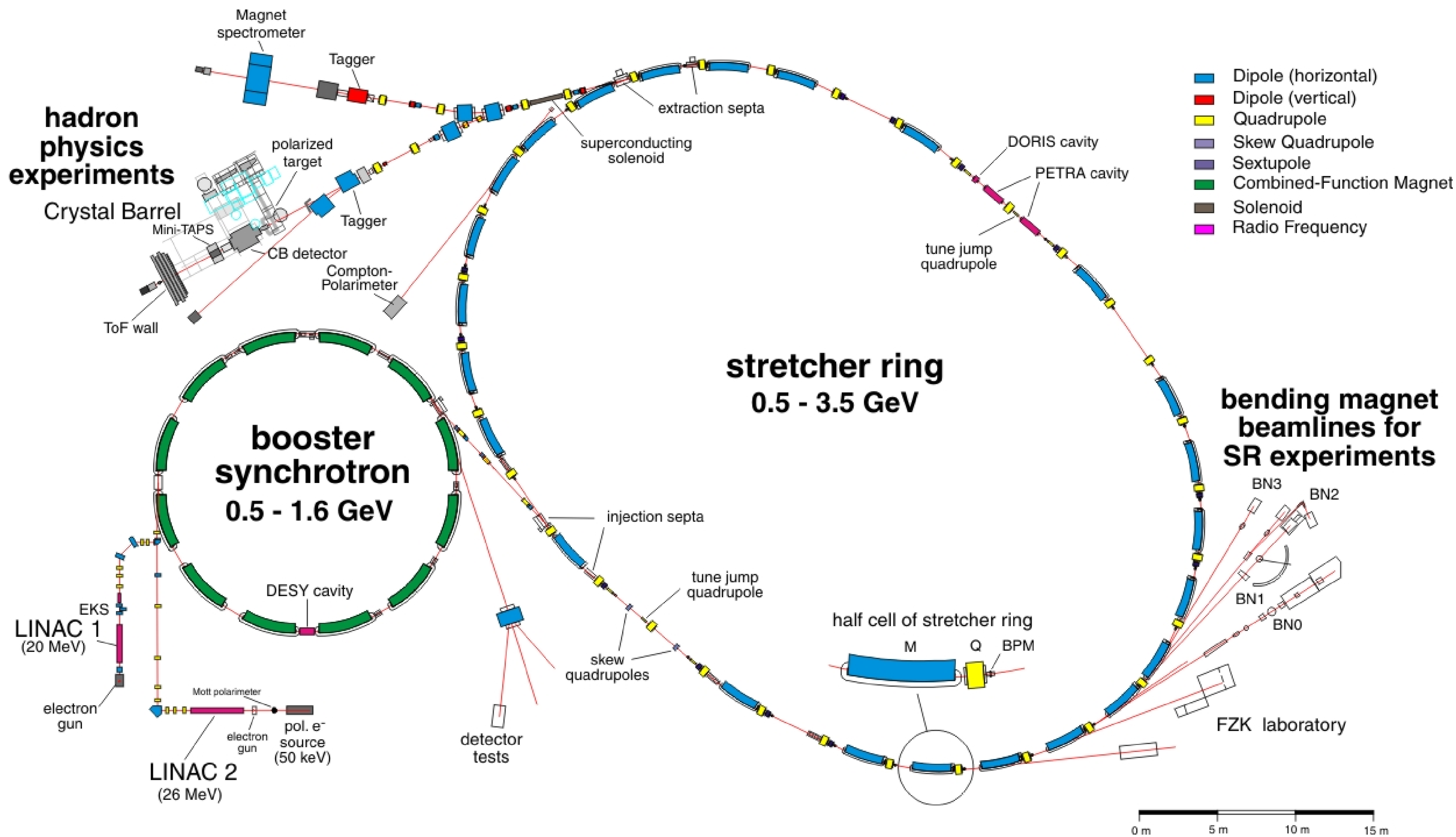
Precision Compton Polarimetry using a counting silicon microstrip detector

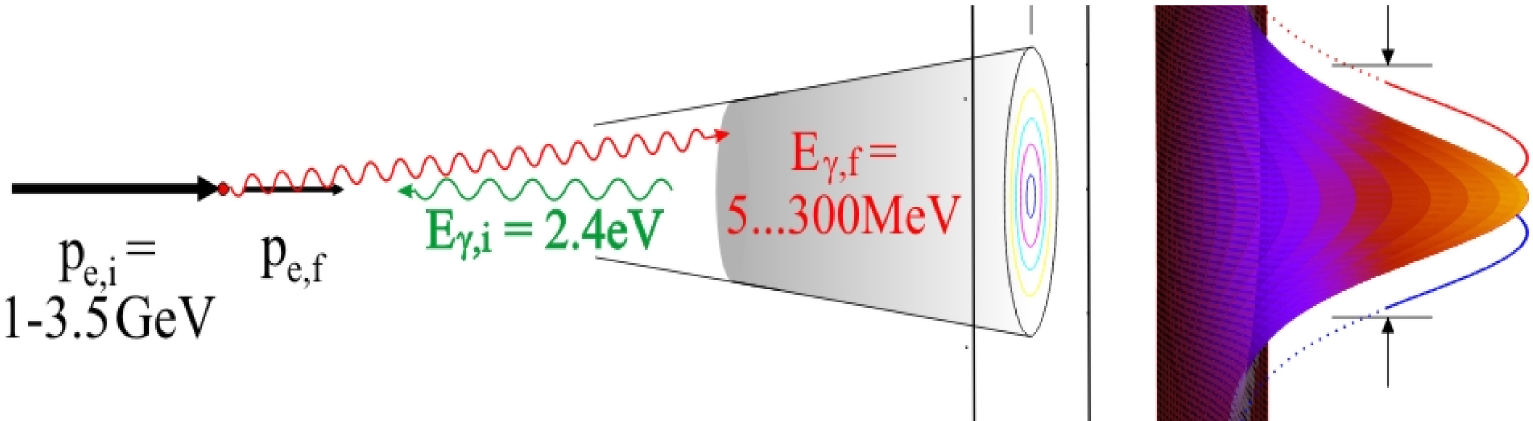
- Compton Polarimetry
- Simulations
- Detector Design
- Laser Beam Line
- Other possible beam diagnostics

Overview



Magnet spectrometer
Tagger
hadron physics experiments
Crystal Barrel
polarized target
Mini-TAPS
Tagger
CB detector
Compton-Polarimeter
ToF wall
extraction septa
superconducting solenoid
DORIS cavity
PETRA cavity
tune jump quadrupole
Dipole (horizontal)
Dipole (vertical)
Quadrupole
Skew Quadrupole
Sextupole
Combined-Function Magnet
Solenoid
Radio Frequency
stretcher ring
0.5 - 3.5 GeV
bending magnet beamlines for SR experiments
BN3
BN2
BN1
BN0
booster synchrotron
0.5 - 1.6 GeV
injection septa
tune jump quadrupole
DESY cavity
skew quadrupoles
half cell of stretcher ring
M
Q
BPM
EKS
LINAC 1
(20 MeV)
electron gun
Mott polarimeter
electron gun
pol. e⁻ source
(50 keV)
LINAC 2
(26 MeV)
detector tests
FZK laboratory
0 m
5 m
10 m
15 m

Compton Scattering



Differential cross section:

$$\frac{d\sigma}{d\Omega^*}(\vec{S},\vec{P}) = \Sigma_0 + \Sigma_1(S_1) + \Sigma_2(S_3,\vec{P})$$

Compton kinematics:

$$K_f^* = \frac{K_i^*}{1 + K_i^* \cdot (1 - \cos\vartheta^*)}$$

Term for the polarized electrons:

transversal

$$\Sigma_2(S_3,\vec{P}) = -S_3 P_Z \cdot C K_f^* \sin\vartheta^* (1-\cos\vartheta^*) \sin\varphi$$

spatial asymmetry

$$-S_3 P_S \cdot C K_f^* (1-\cos\vartheta^*)(K_f^* + K_i^*)\cos\vartheta^*$$

counting rate asymmetry

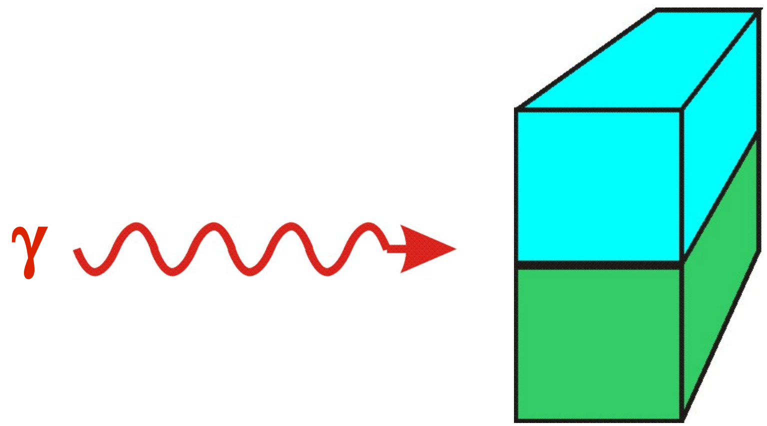
longitudinal

$$C = \frac{r_e^2}{2} \cdot \left(\frac{K_f^*}{K_i^*} \right)$$

Different types of Compton Polarimeters for transversal polarized electrons

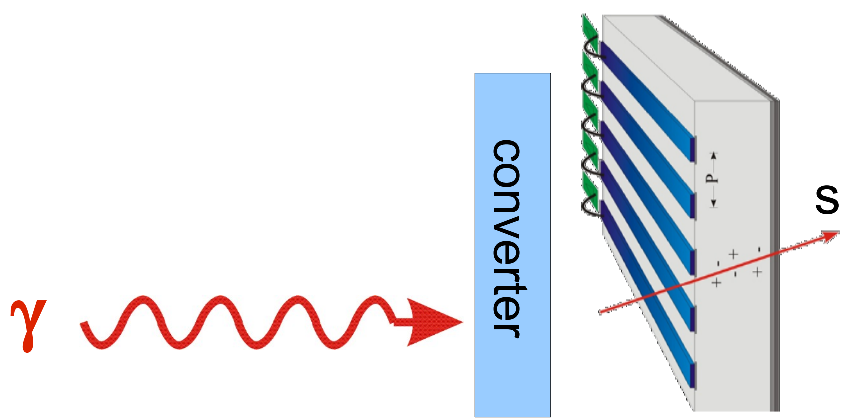
We can measure either:

- **integral up down counting rate asymmetry**



crystal detectors

- **shift of the center of the spatial distribution**

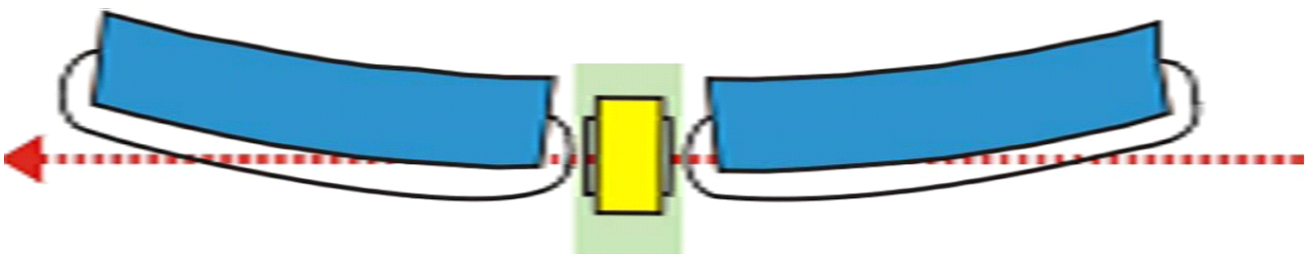


silicon microstrip detector

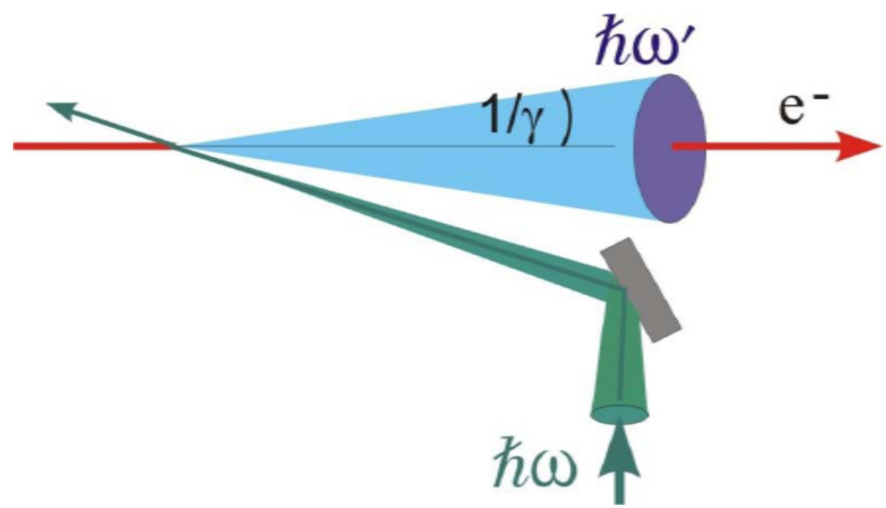
Design Criteria

- Electron scattering on restgas causes high energy background

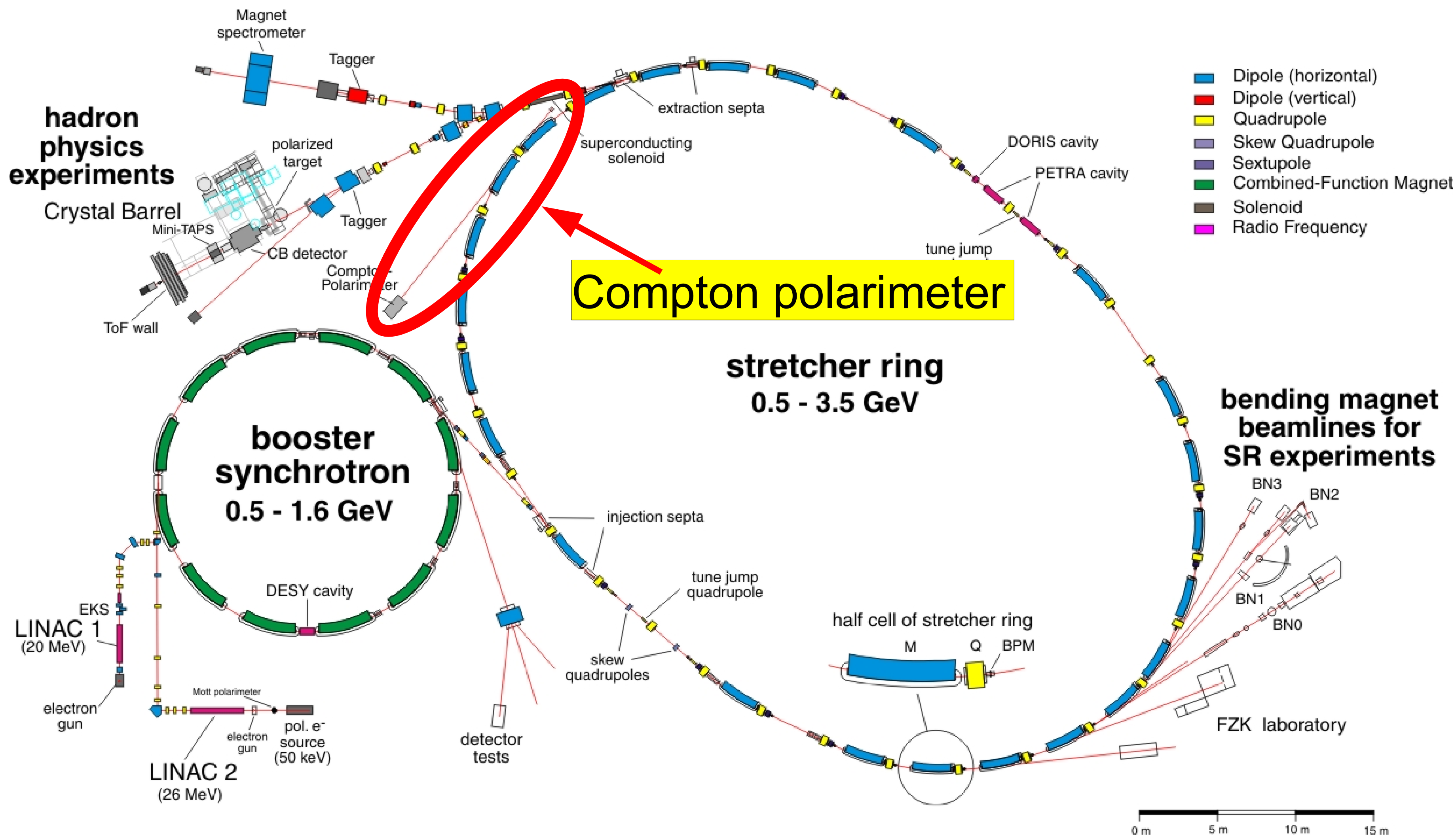
$\rightarrow$ **use only a short straight section**



- crossing angle: $\delta \approx 3$mrad
- interaction region length: 0.7 m
- distance i.r.$\leftrightarrow$ detector: 15 m



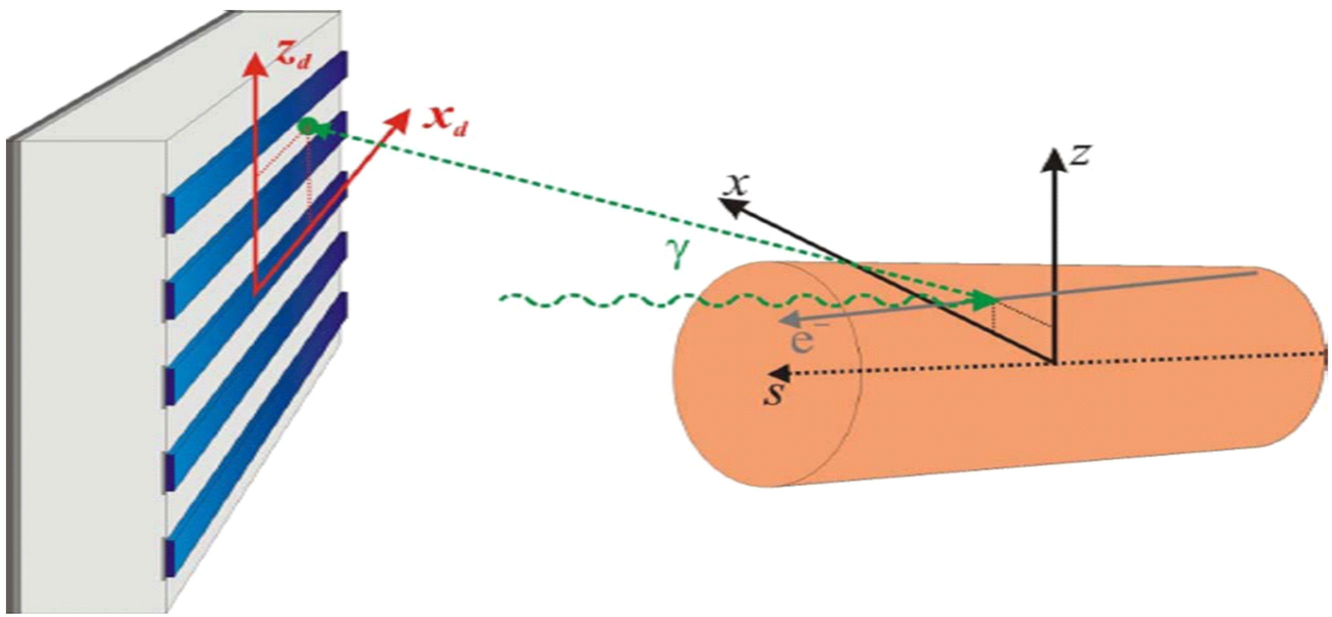
Design Criteria



Simulation of the Compton Process

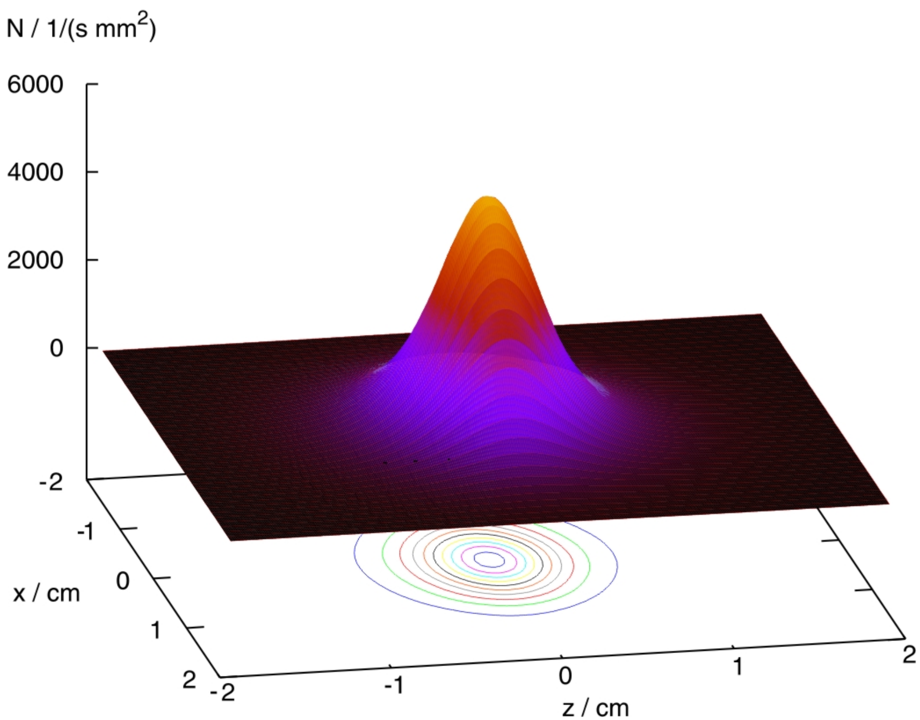
Numerical integration over the 5 dimensional phase space

$$N(x_d, z_d) = \int_{S_0}^{S_1} ds \int_{Z_0}^{Z_1} dz \int_{X_0}^{X_1} dx \int_{Z'_0}^{Z'_1} dz' \int_{X'_0}^{X'_1} dx' \frac{d\sigma}{d\omega}(\vartheta, \phi) \sin(\vartheta) \frac{\partial(\vartheta, \phi)}{\partial(x, z)} \cdot$$
$$\cdot \rho_e(x, z, x', z', s) \cdot \rho(x, z, s)$$

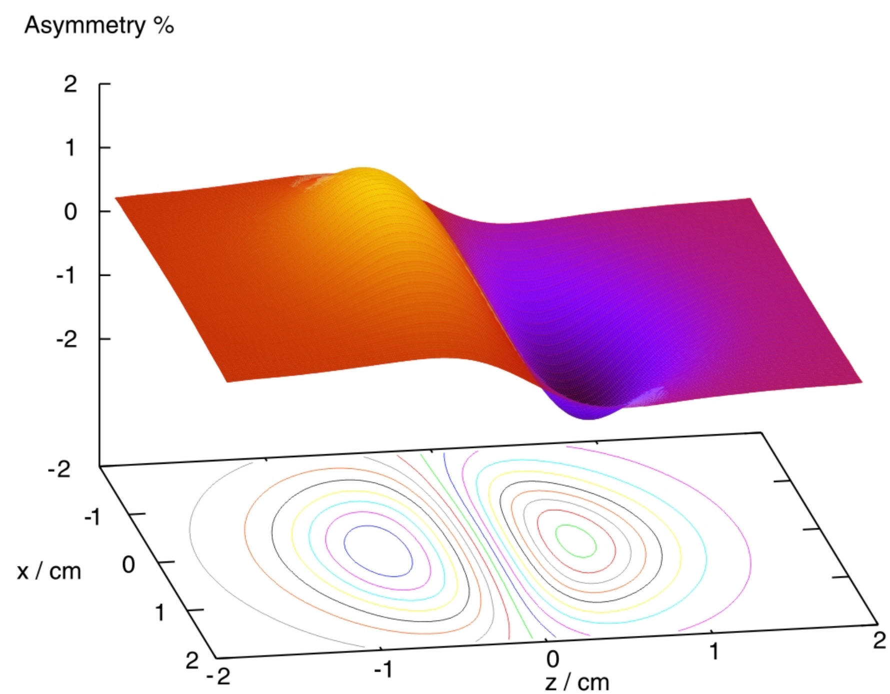


Simulation of the Compton Process

Distribution of the backscattered photons

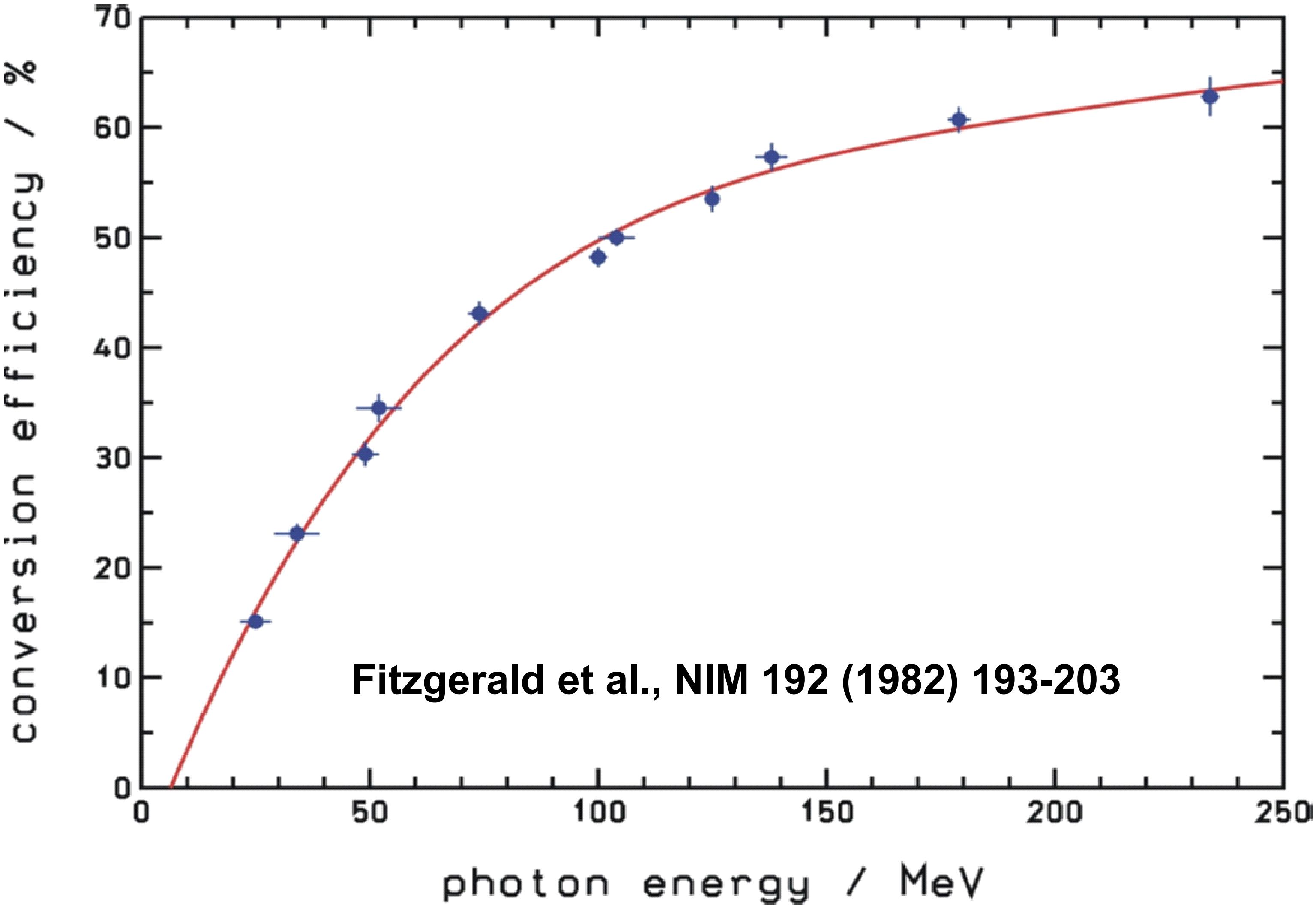


Rate asymmetry

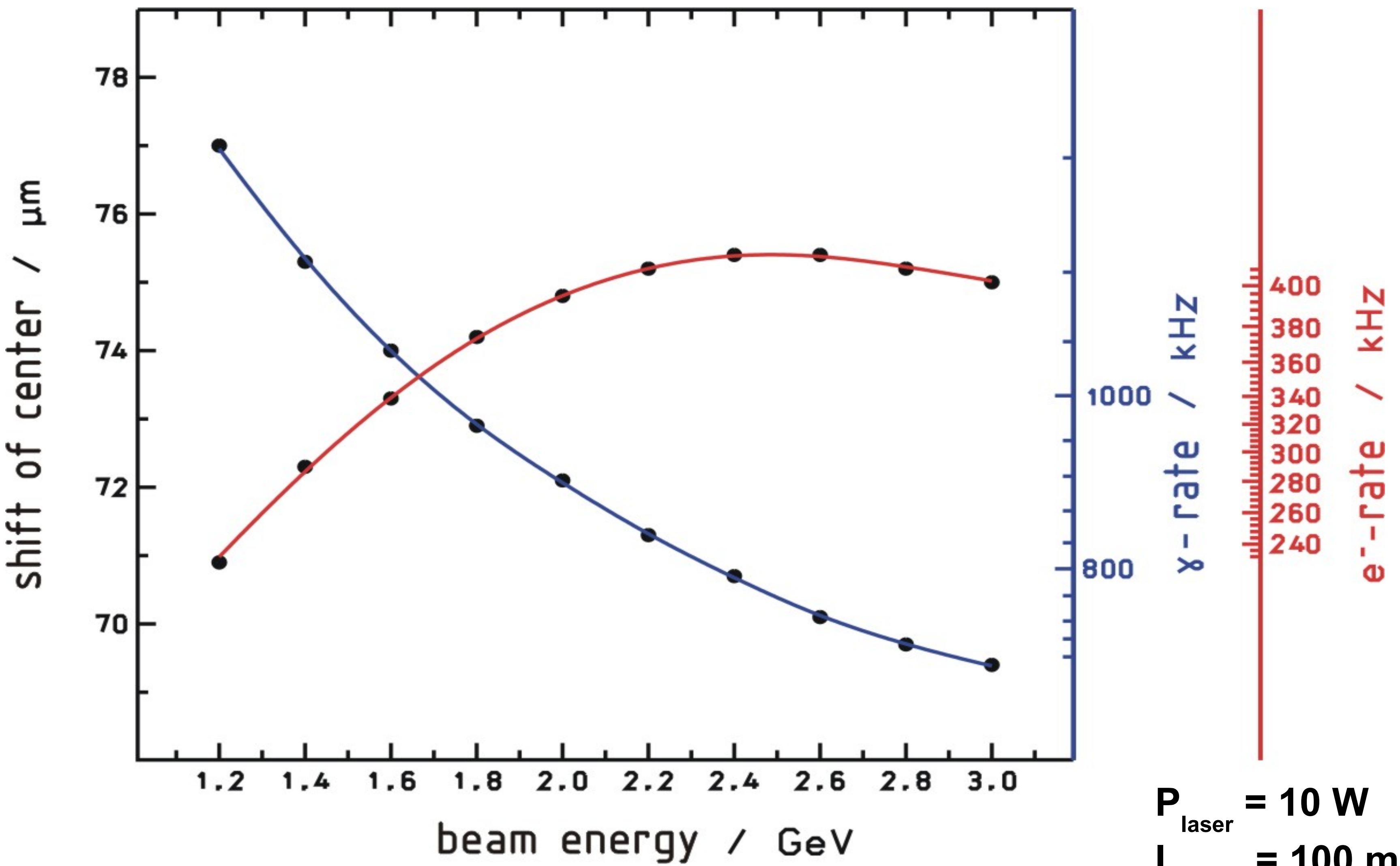


Simulation of the Compton Process

e^+/e^- pair conversion ; d=1.7 X_0



Analyzing Power



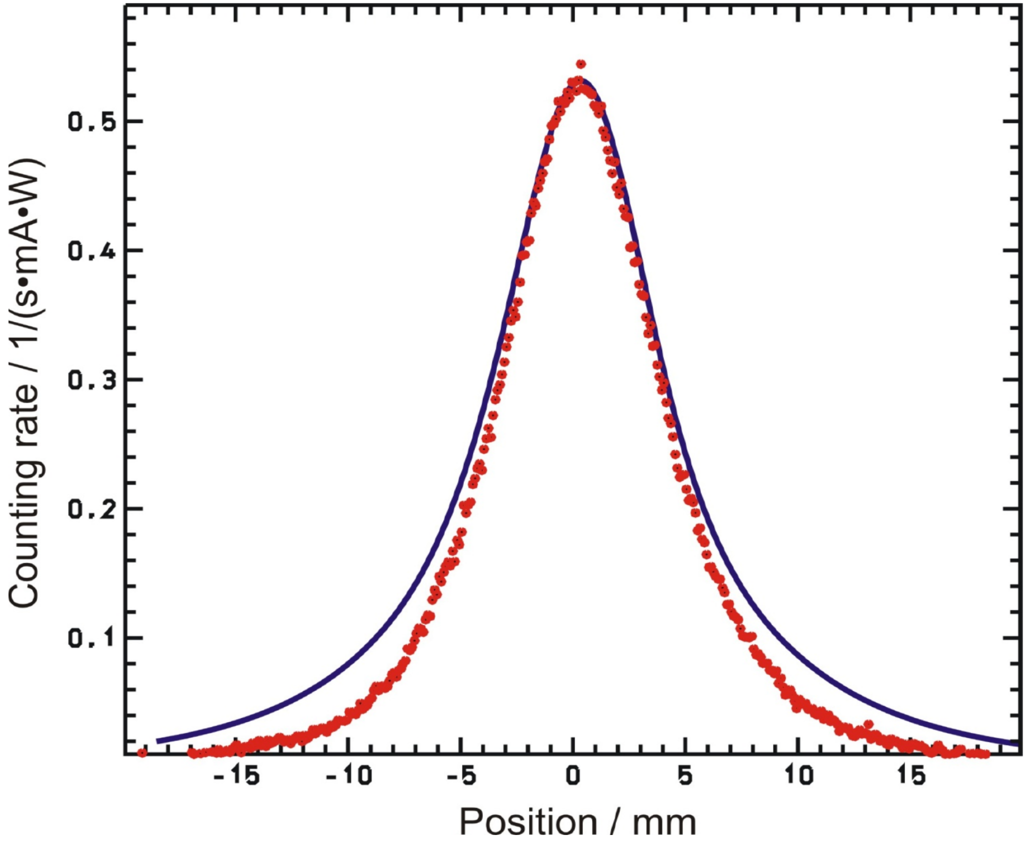
P_{laser} = 10 W

$I_{e\text{-}beam}$ = 100 mA

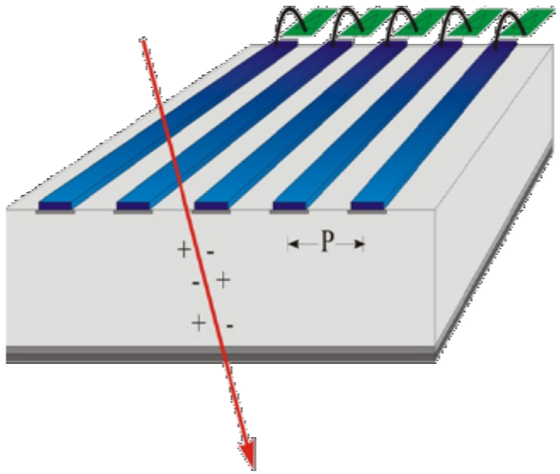
$d_{converter}$ = 1.7 X_0

Simulation of the Compton Process

Comparison between simulation and a real measurement with a previous prototype detector



Required Pitch

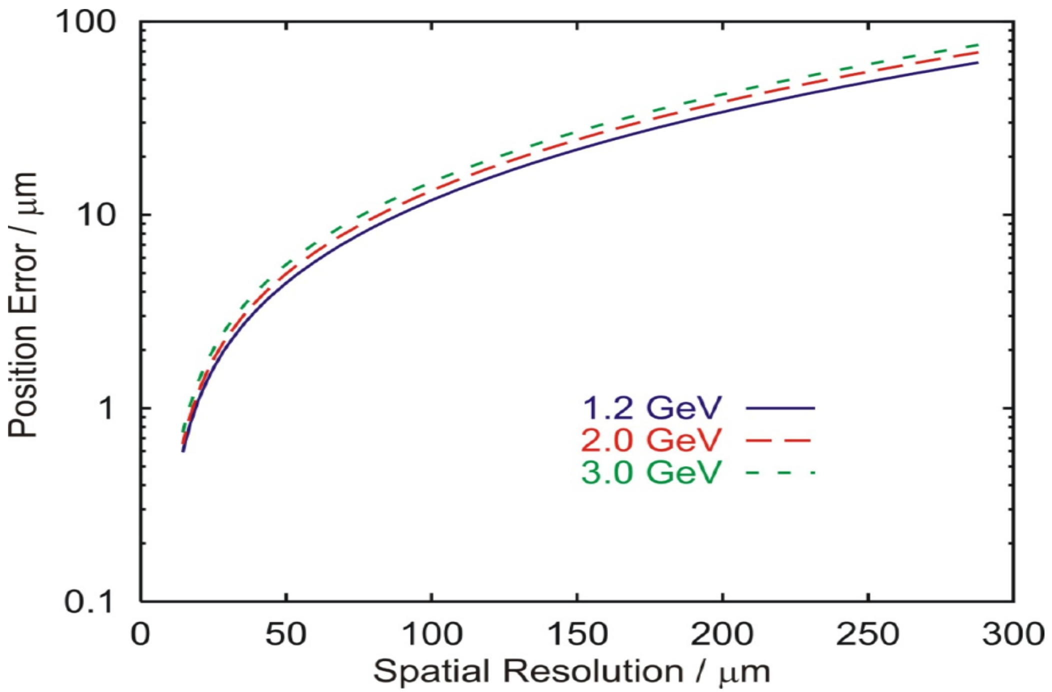


spatial resolution:

$$\Delta z_{det} = \frac{p}{\sqrt{12}}$$

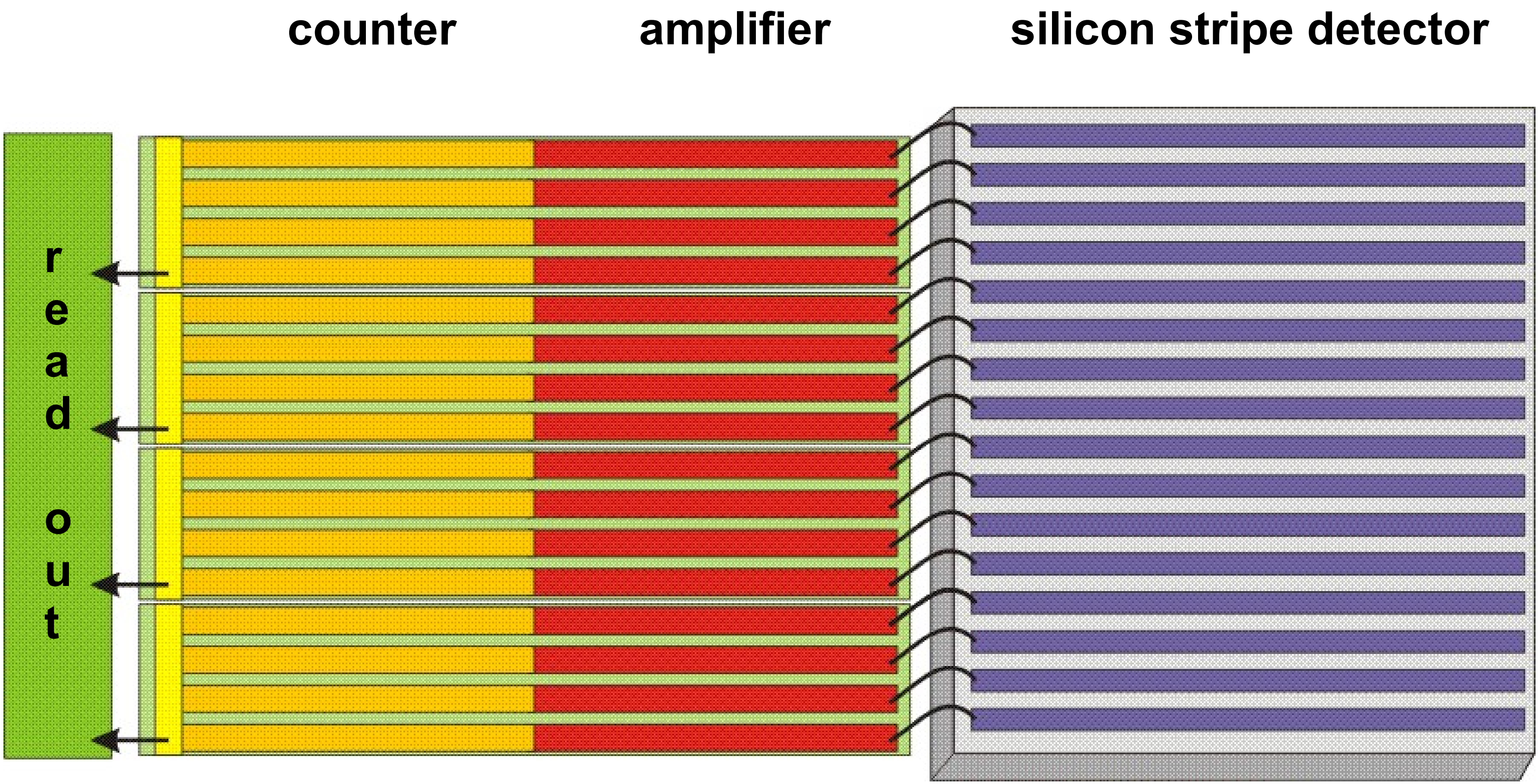
achievable position error:

$$\Delta \bar{z} = \sqrt{\frac{\sigma_z^2}{N^2} + \frac{\sum_i n_i^2}{N^2} \cdot \Delta z_{det}^2}$$

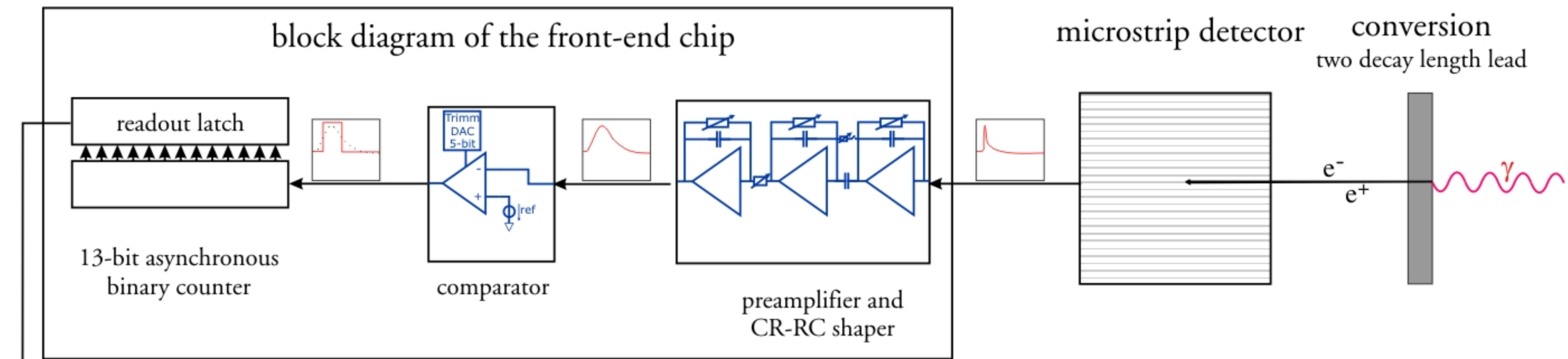


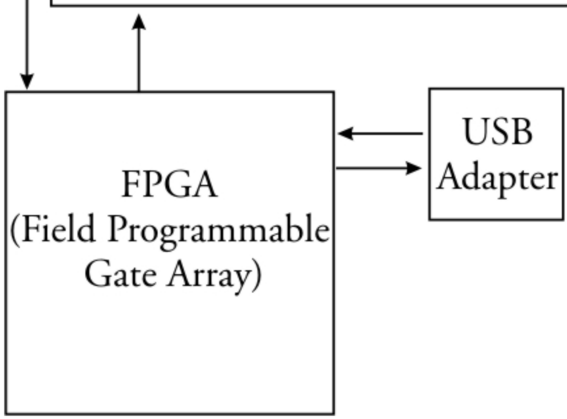
$$\Delta P \leqslant 1\,^0/_0 \longleftrightarrow \Delta z \leqslant 0.7\,\mu m \longleftrightarrow p \approx 50\,\mu m$$

Detector Design



Detector Design





silicon microstrip detector (BABAR 1)

- 768 strips with 50 µm pitch $(42.4 * 41.3\ mm^2)$
- resolution: 14 µm

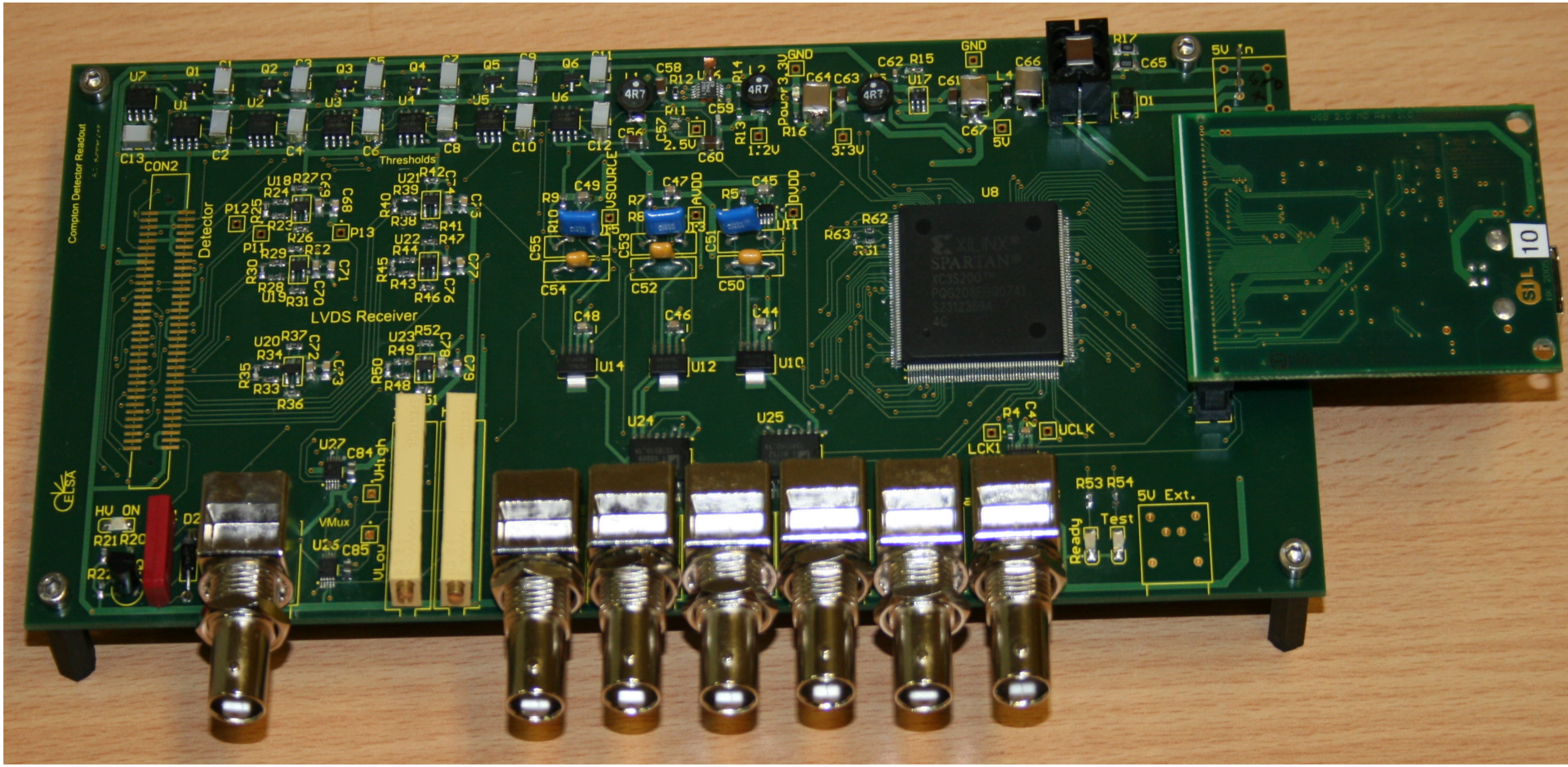
front-end chip

- high rate acceptance (10 - 150 Mhz)
- digital part build in LVDS technology
- internal logic controls the readout process

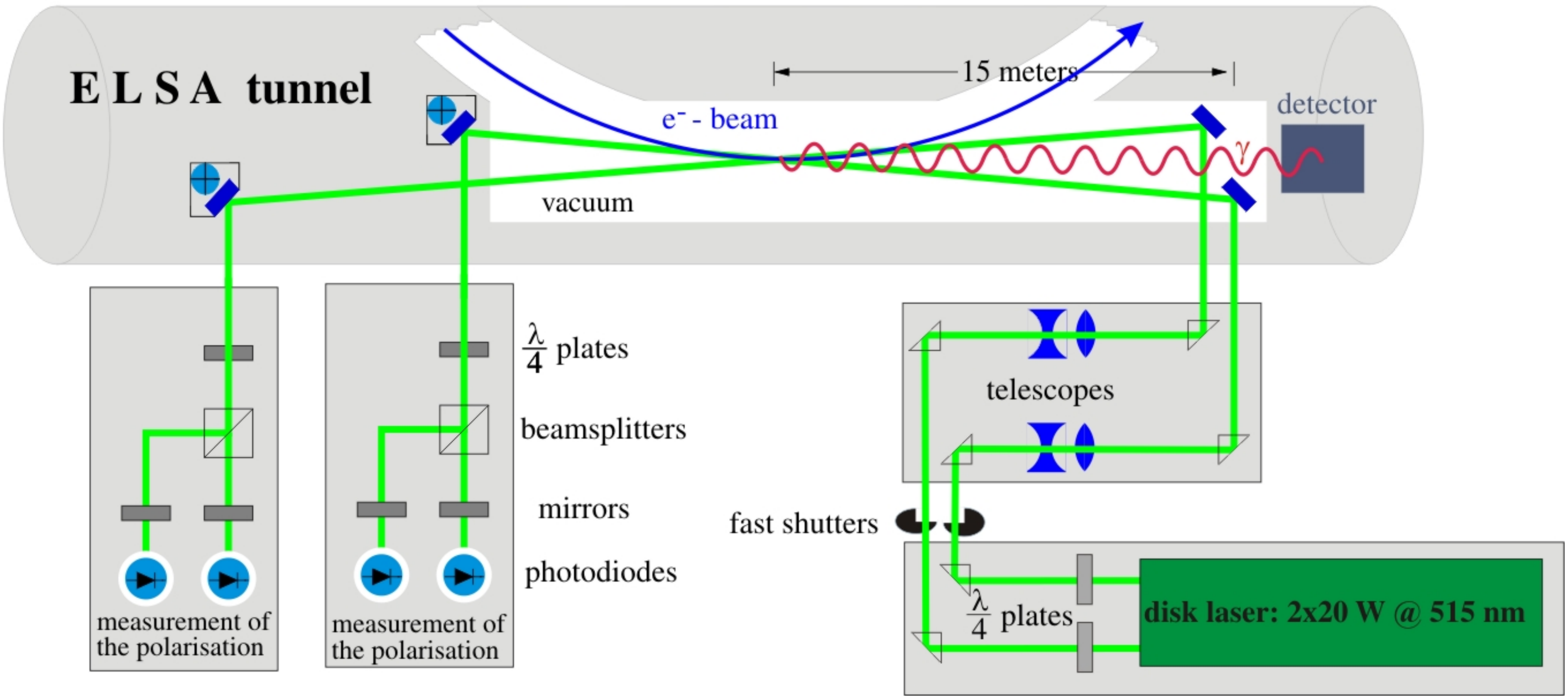
Detector Design

Measurement program:

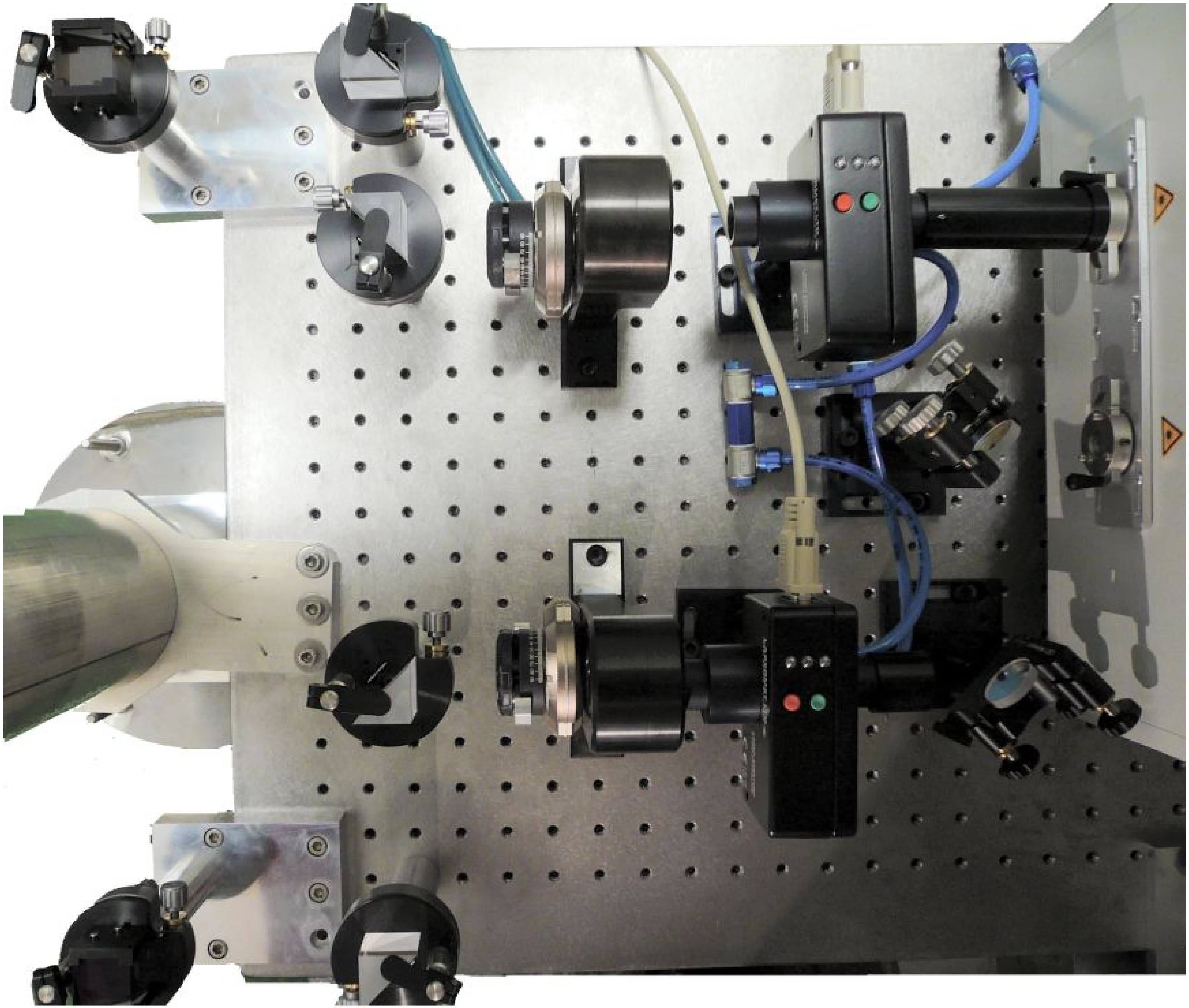
•S_3=1	•S_3= -1
•background	•background
•S_3= -1	•S_3=1



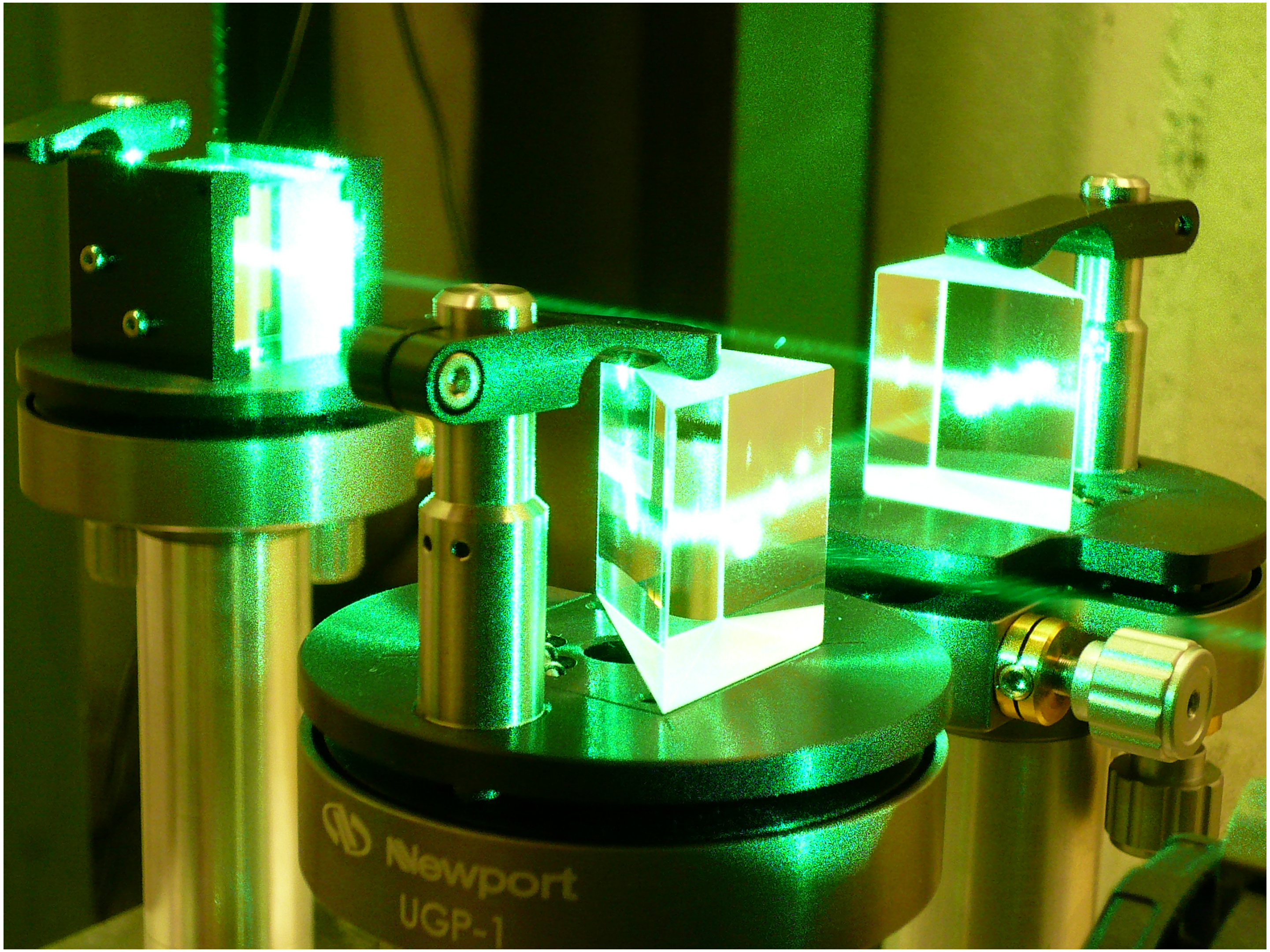
Laser Beam Line



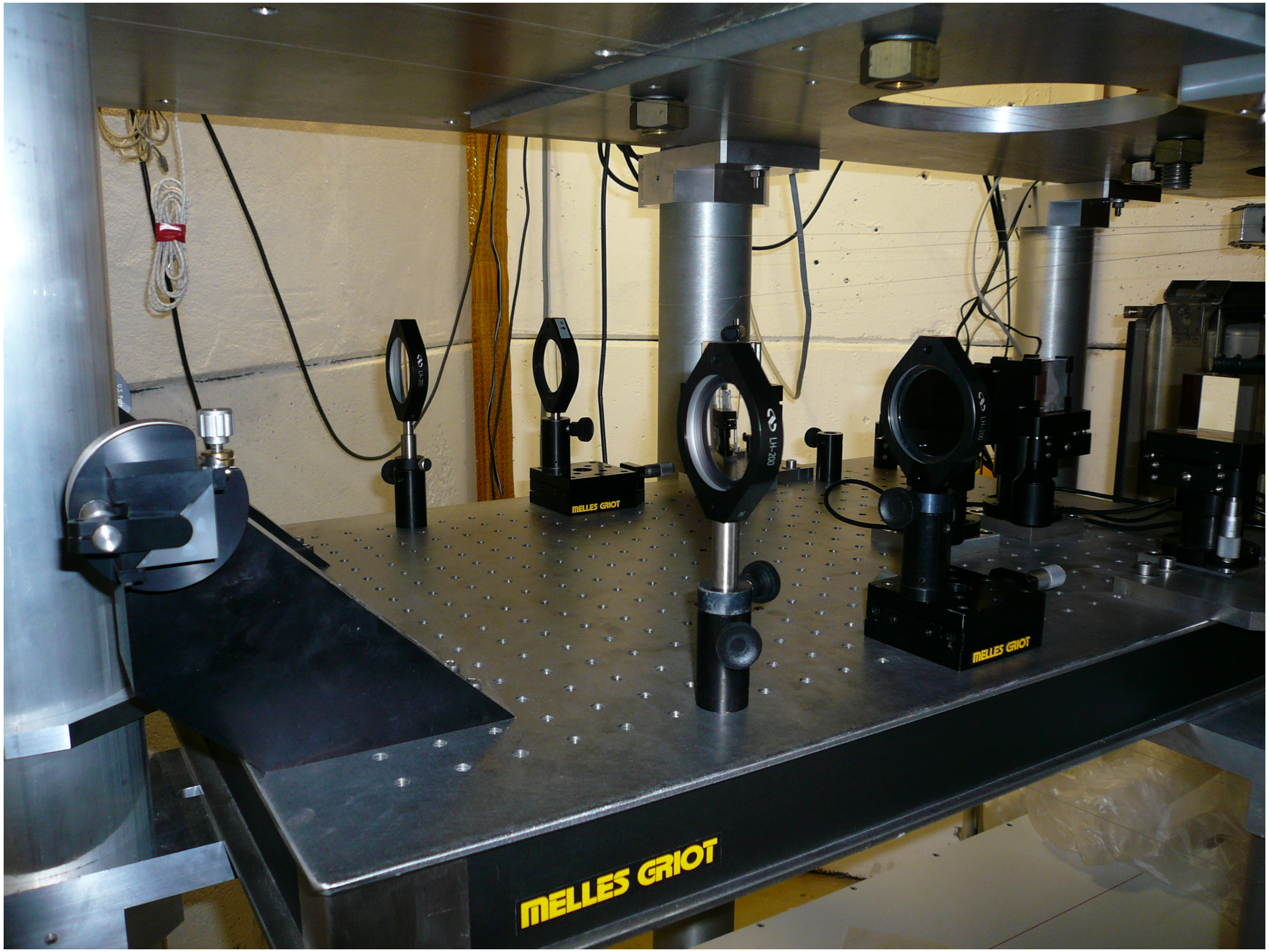
Laser Beam Line



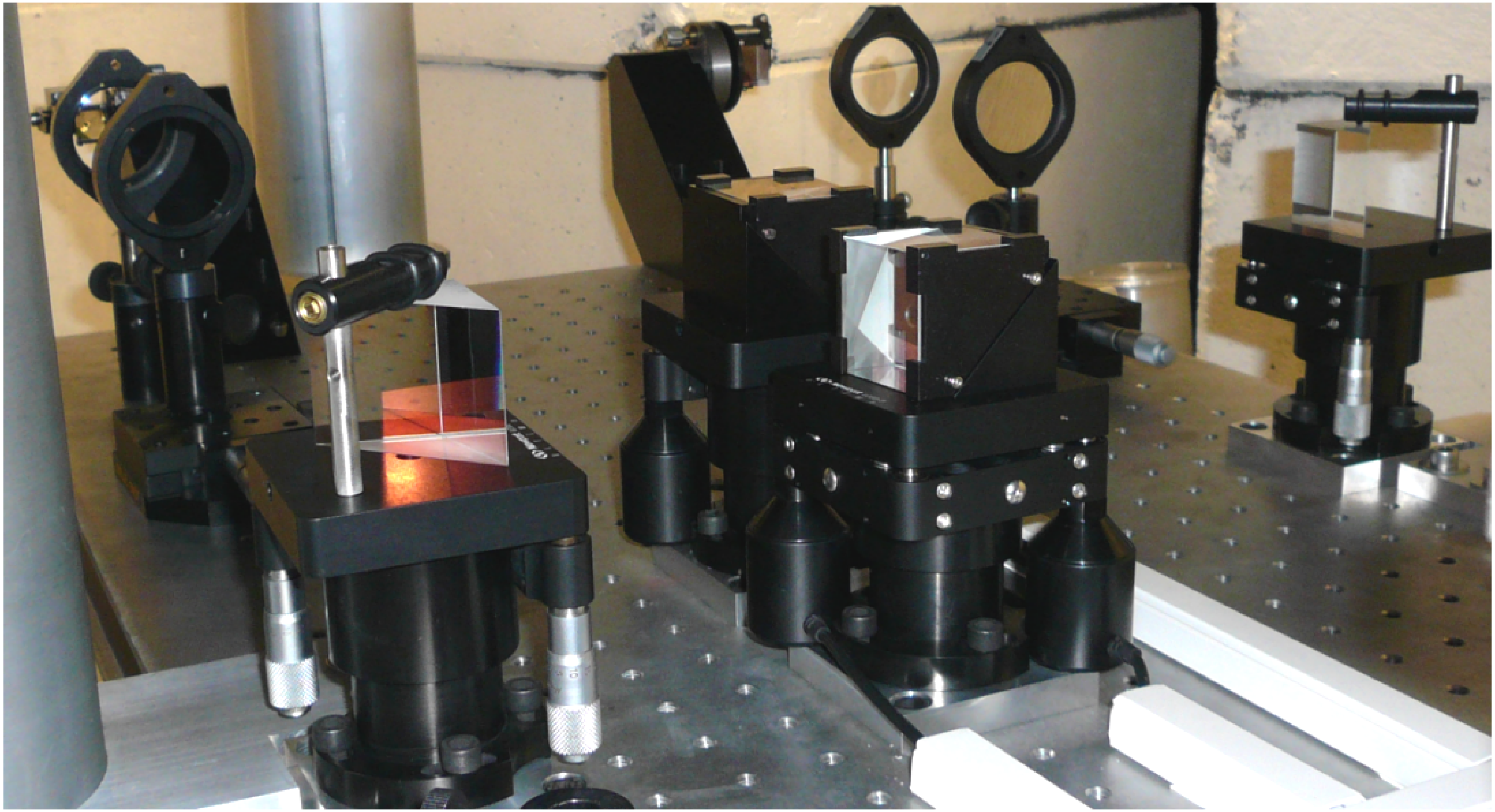
Laser Beam Line



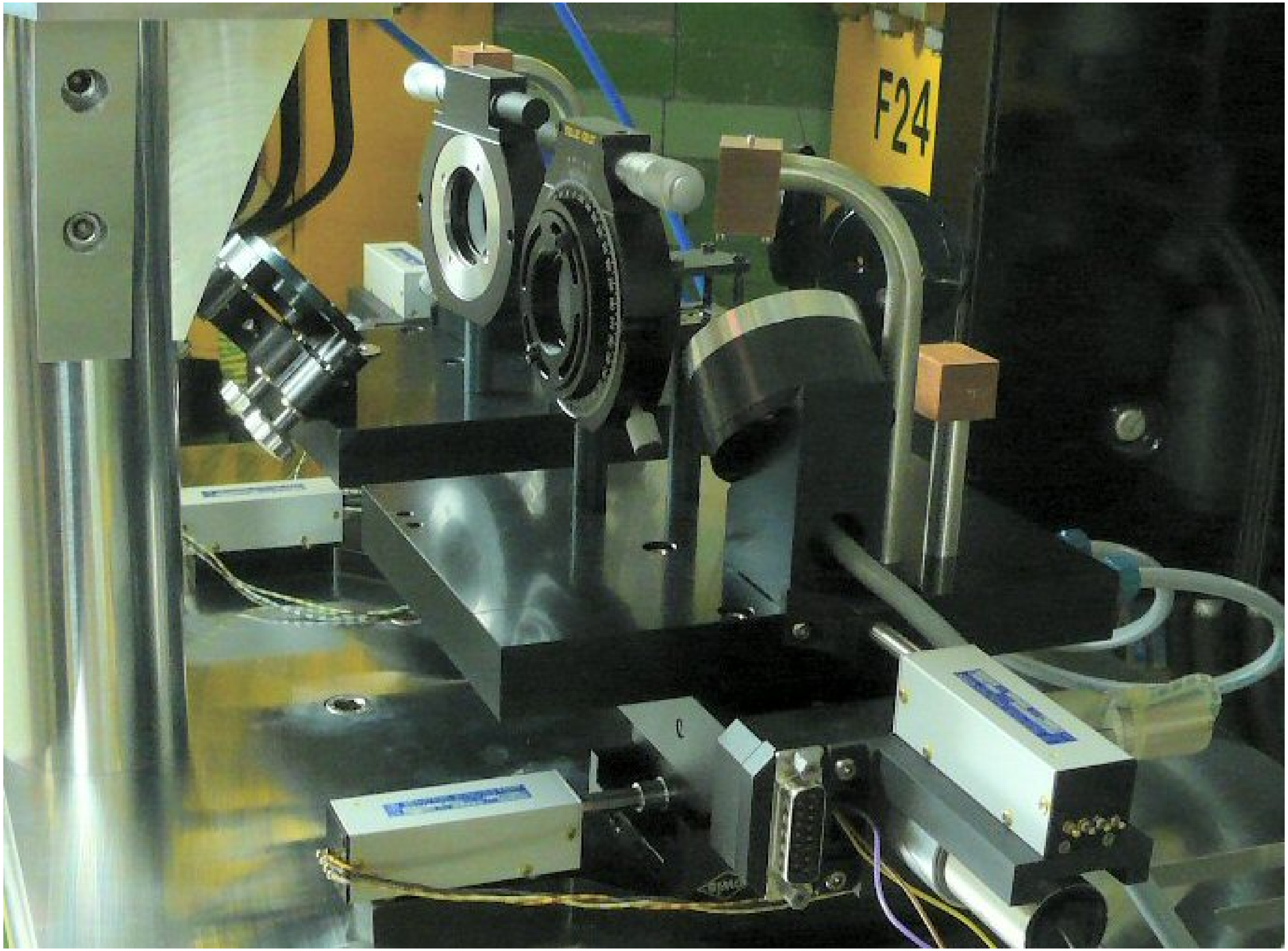
Laser Beam Line



Laser Beam Line

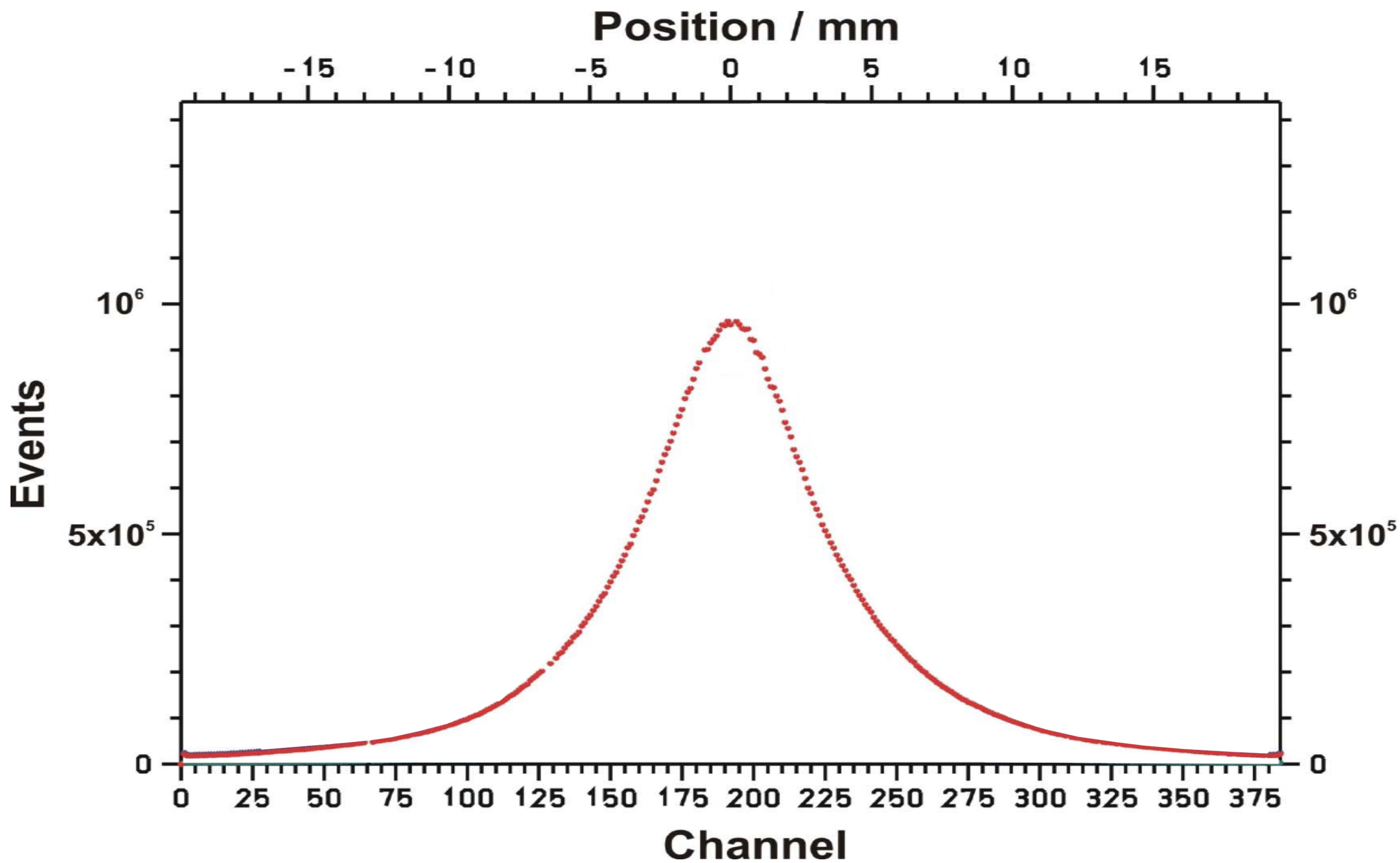


Laser Beam Line



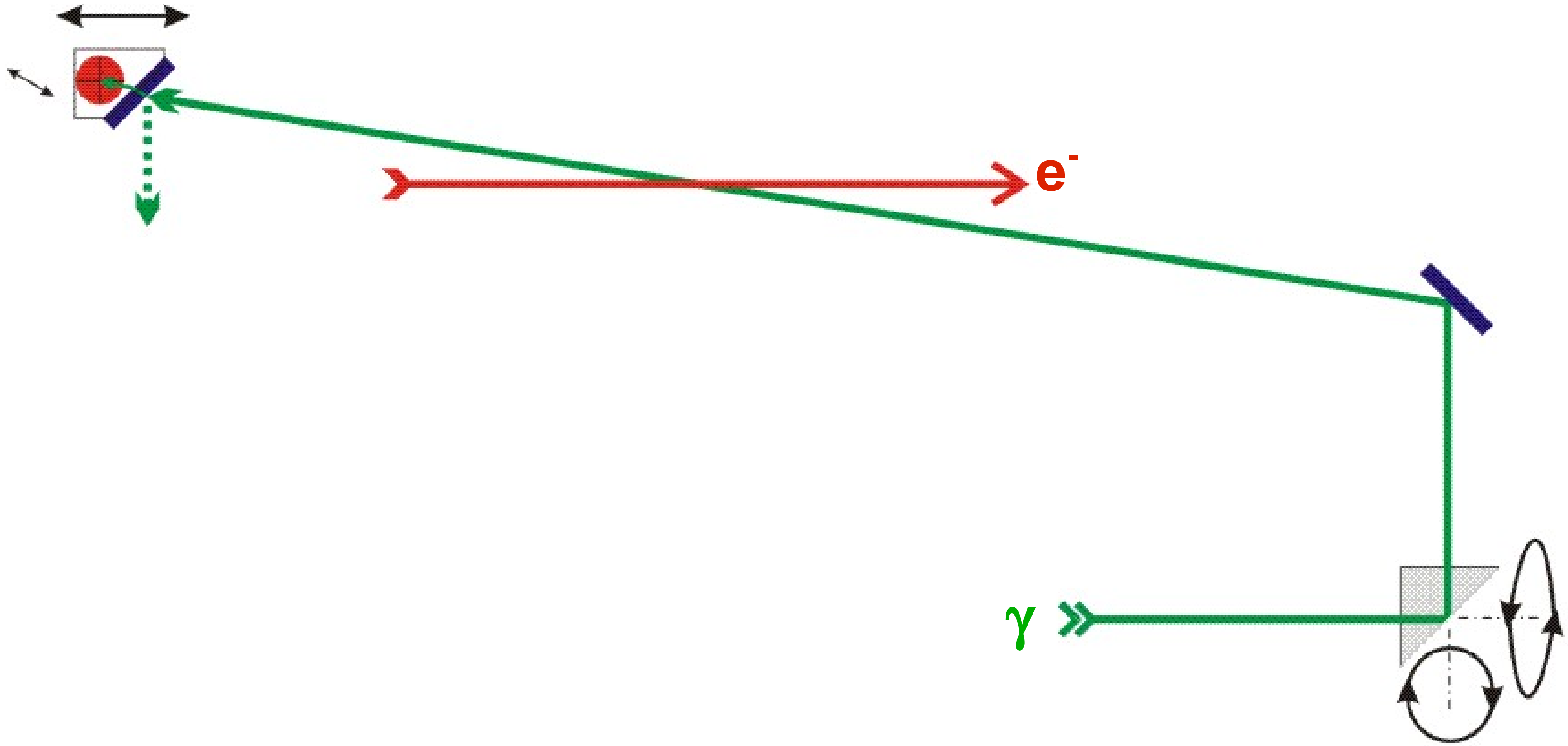
Beamdiagnostics

- Measurement without laser beam delivers profile of convolution of the e^- beam width and divergence



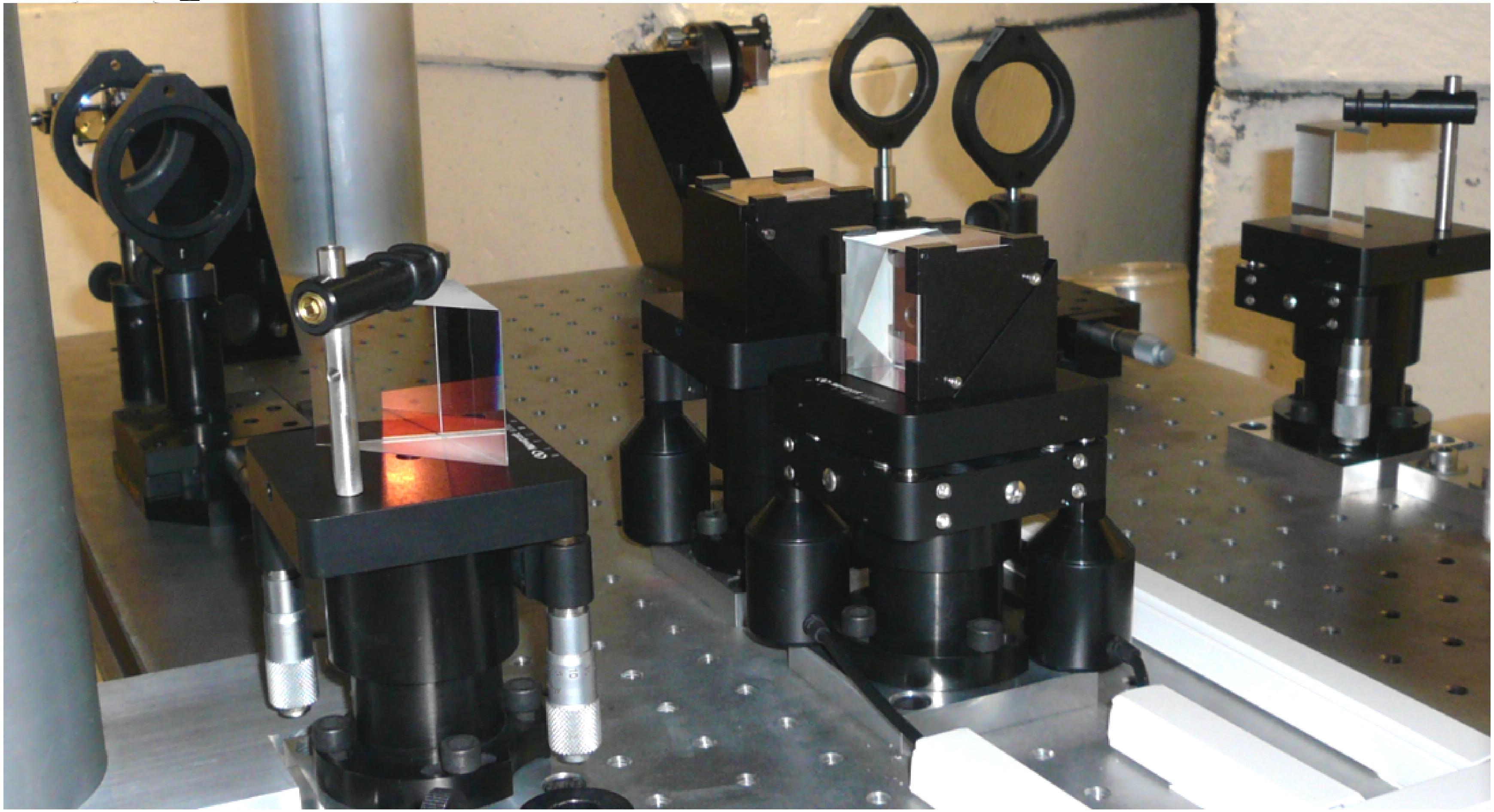
Beamdiagnostics

Scanning of the horizontal e^- beam width



Beamdiagnostics

Scanning of the horizontal e^- beam width



Outlook

- First detector tests this year with a smaller detector
- Complete detector and laser setup in spring next next year
- In the future the capabilities as a beamdiagnosis element will be investigated