Two candidates for beryllium tubes in Transverse Polarimeter design

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Outline

- Motivation
- Method
- Compton scattering physics
- Compton polarimeter simulation
- Layout discussion
- Conclusion

Motivation

➢ **Transverse polarization**

- Calibrate beam energy by the **resonant depolarization (RD)** method using transverse polarized beams. *Soviet Physics Uspekhi* **14** (1972) 695.
- Observation of **CP violation** *Phys. Rev.* **D 70** (2004) 036005.
- **Explore new physics**: distinguishing between different models of the extra dimensions in indirect searches for massive gravitons *Physical Reports* **D 460** (2008) 131.
- ……

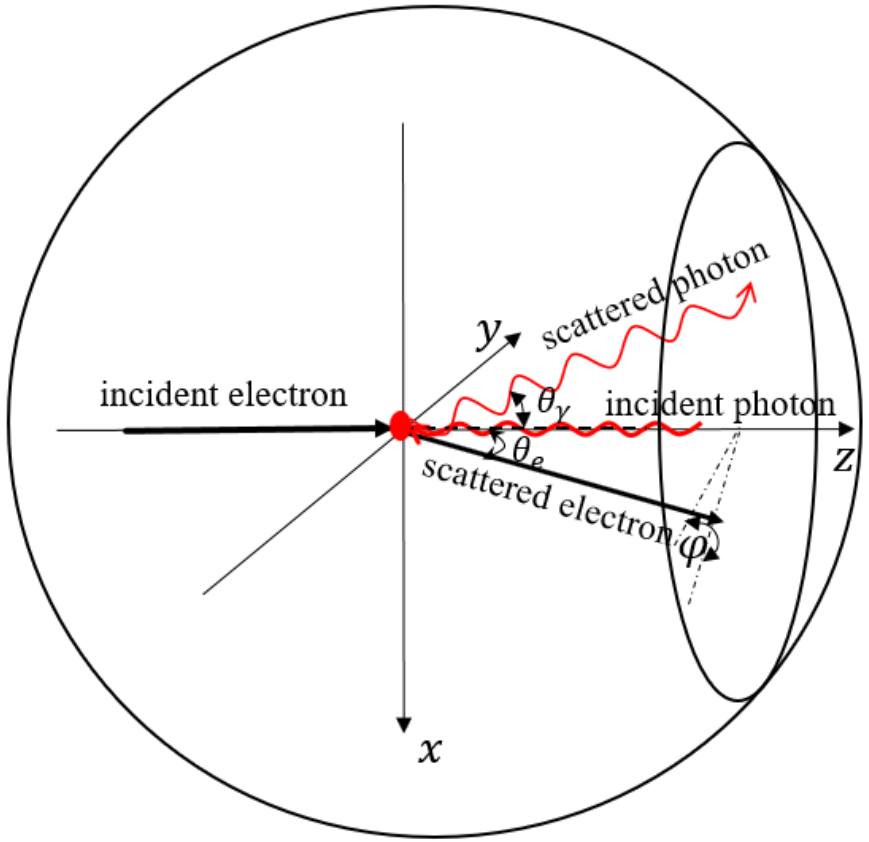
<u>Requirements:</u>

- Transverse polarization is built in storage rings by **Sokolov-Ternov effect**. *Soviet Physics Doklady* **8** (1964) 1203.
- For RD to calibrate beam energy, a beam with transverse polarization of 5%~10% is required.
- Monitor the beam polarization continuously throughout physics runs in a short time of a few minutes is necessary.

Method

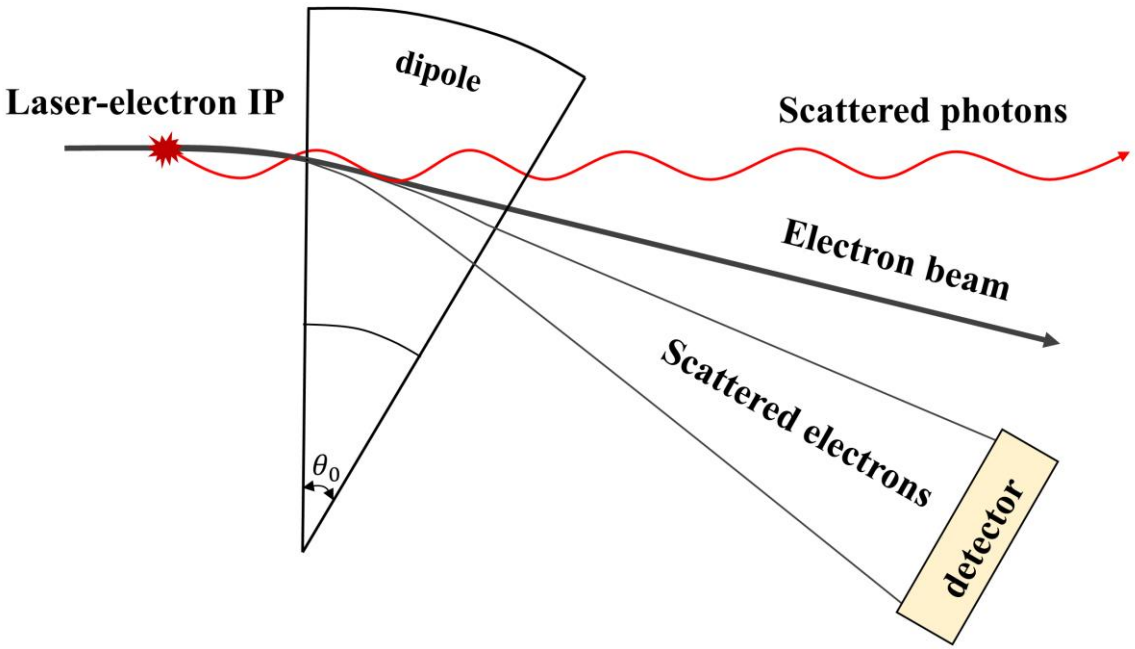
- Compton polarimeter:
  - $e + \gamma \rightarrow e + \gamma$
  - non-invasive
  - Scattered electrons and scattered photons can be independent to measure the beam polarization
- Møller polarimeter:
  - $e + e \rightarrow e + e$
  - Low beam current
  - Suitable for energy 100 MeV ~ 50 GeV.
- Mott polarimeter
  - Operate in beam energy below 10 MeV
- Touschek lifetime measurement:
  - Require a system that Touschek lifetime is dominated.
  - require for a highly stable and repeatable machine operation of polarized and unpolarized beams
- “spin-light” polarimeter:
  - transverse polarization: measuring the total synchrotron radiation (SR) power radiated
  - the spatial asymmetry of SR is longitudinal-spin dependent
  - Best suited for the 4 - 20 GeV energy range, for current less than mA

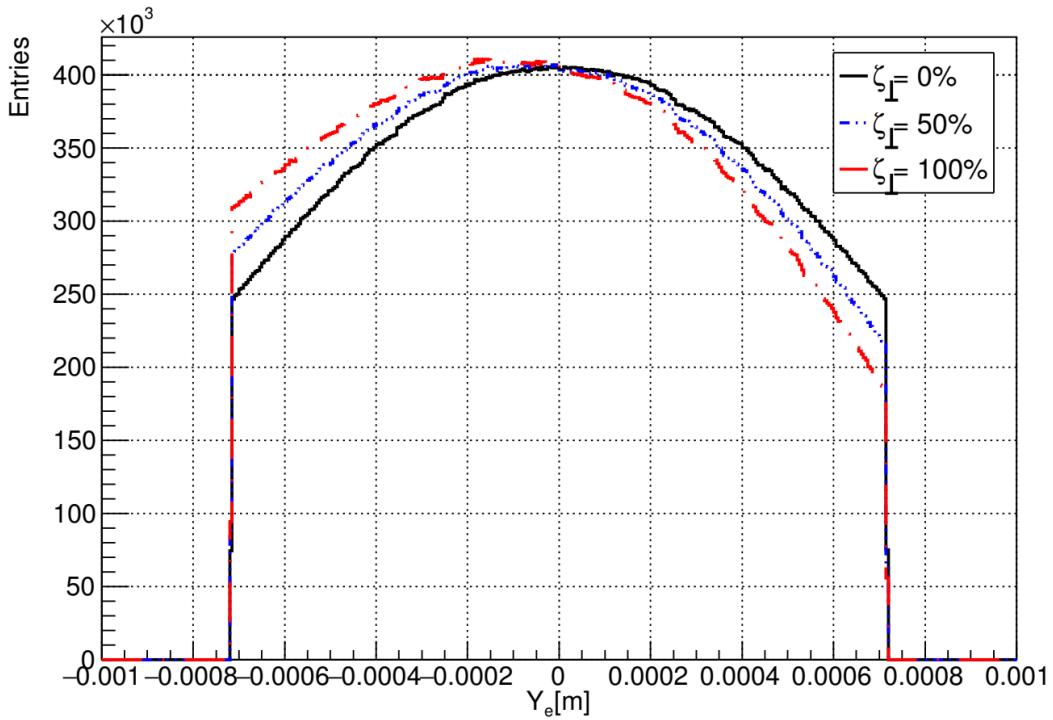
Compton scattering physics



Parameter	value
Beam energy, E	45.5 GeV
Laser wavelength, λ	1064 nm
Laser power, P_L	0.1 GW
Maximum energy of scattered photons, w_{max}	20.34 GeV
Minimum energy of scattered electrons, ε_{min}	25.16 GeV
Maximum electron scattering angle, $\theta_{e_{max}}$	4.54 μrad

Transverse polarimeter



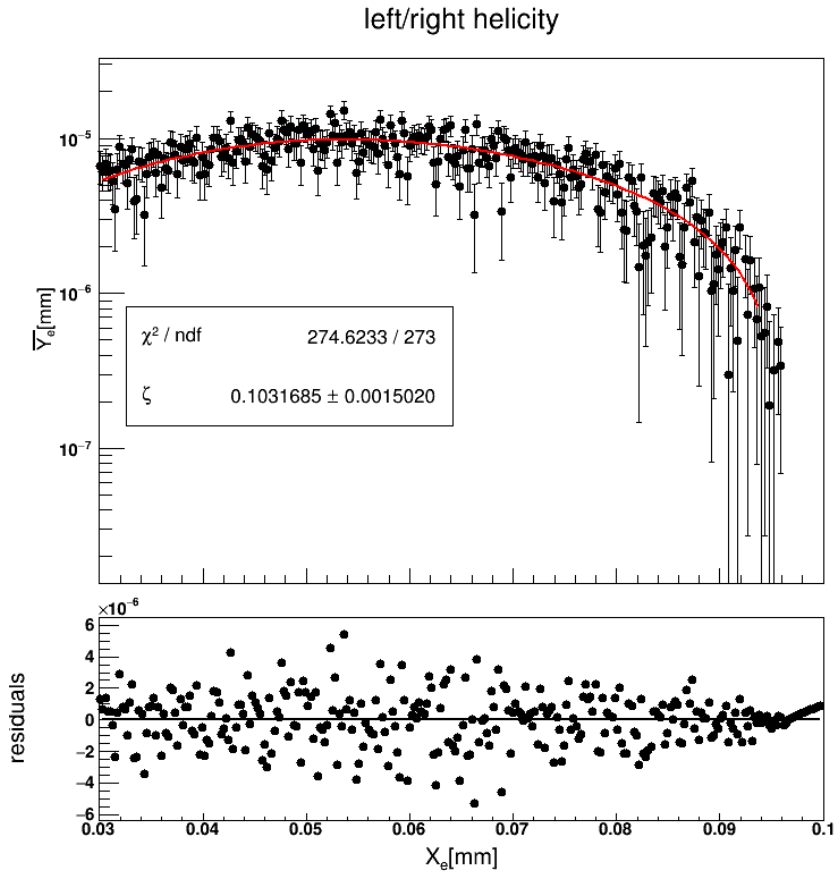


- **A dipole** is arranged to separate the scattered particles from the electron beam.
- CEPC Transverse polarimeter: detecting the spatial distribution of the scattered electrons to measure the transverse polarization of electron/positron beam.

Monte-Carlo simulation

- Fit the spatial distribution of the scattered electrons by analyzing power (Π)

$$A(Y_e) = \bar{Y}_e|_{X_e} = P_\perp \Pi(X_e)$$

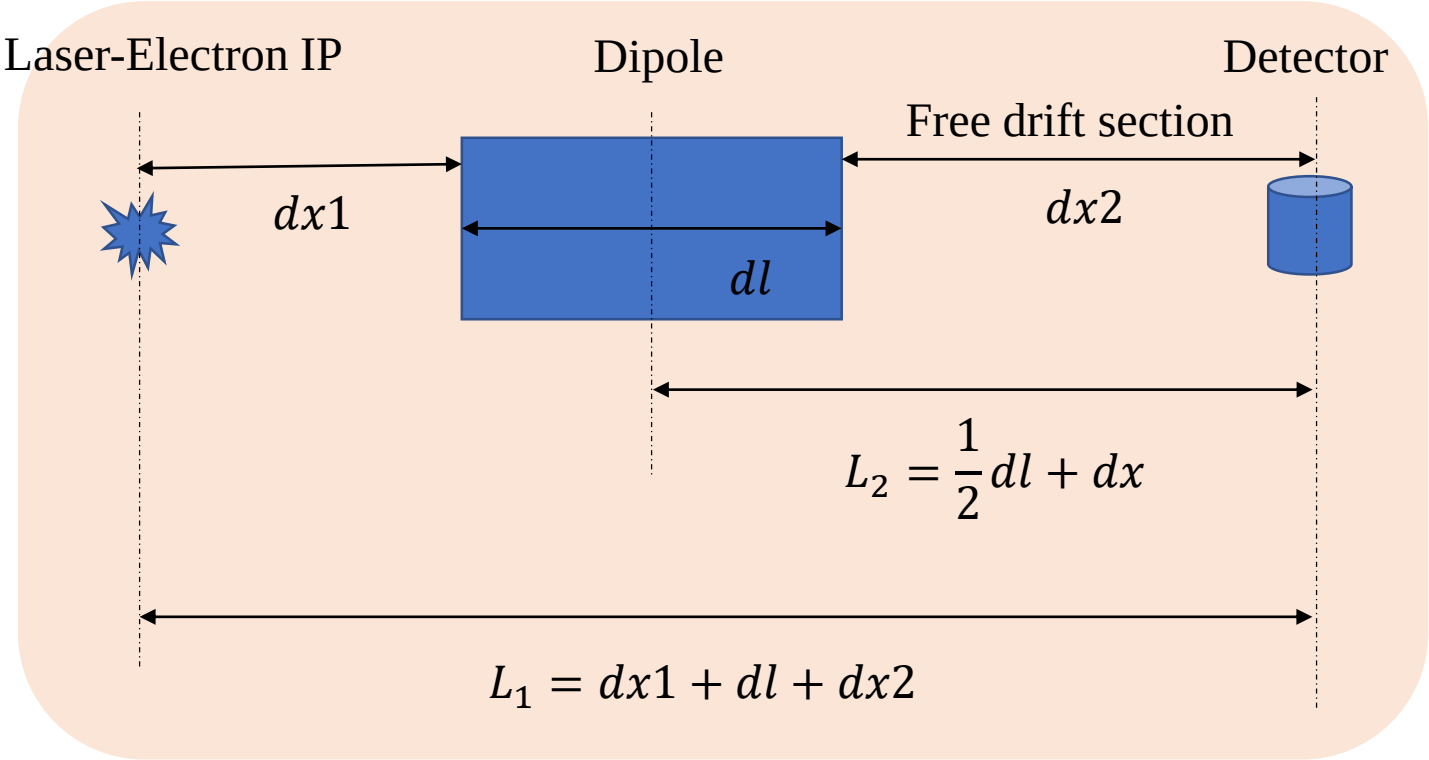


- Statistical error (10% transverse polarization):
  - $\Delta P_\perp / P_\perp \approx 1.5\%$ for about 30 seconds of data taking

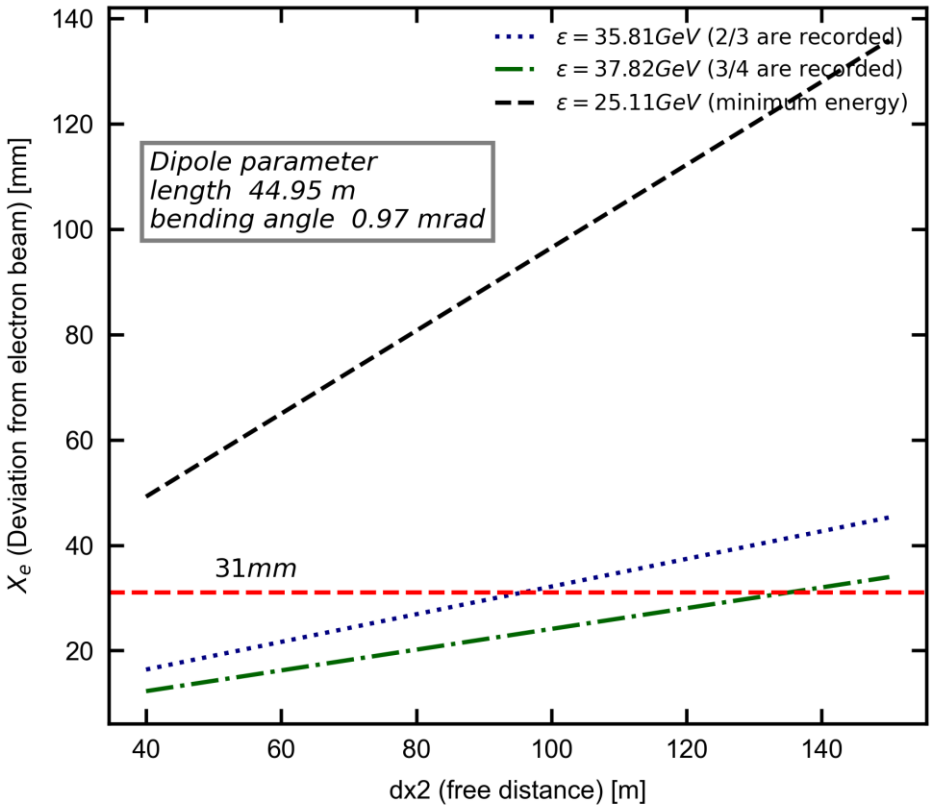
- Potential systematic errors of the transverse polarization measurement for 10% polarization

Sources of systematic uncertainties	$\Delta P_\perp / P_\perp$ %
Dipole strength	0.062%
ΔL_1(IP-to-detector)	0.007%
ΔL_2 (magnet-to-detector)	0.051%
Beam energy	0.0001%
Detector resolution	0.278%
Detector placement	ignored
Laser polarization	0.2 %
Total	< 1%

Layout discussion



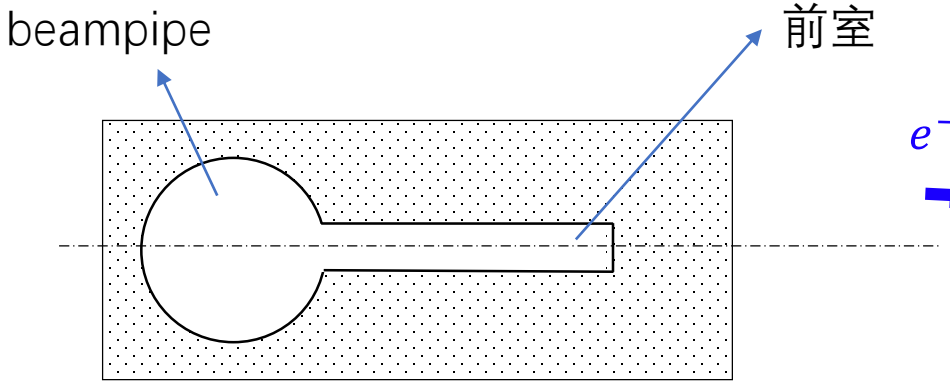
Requirement for free distance



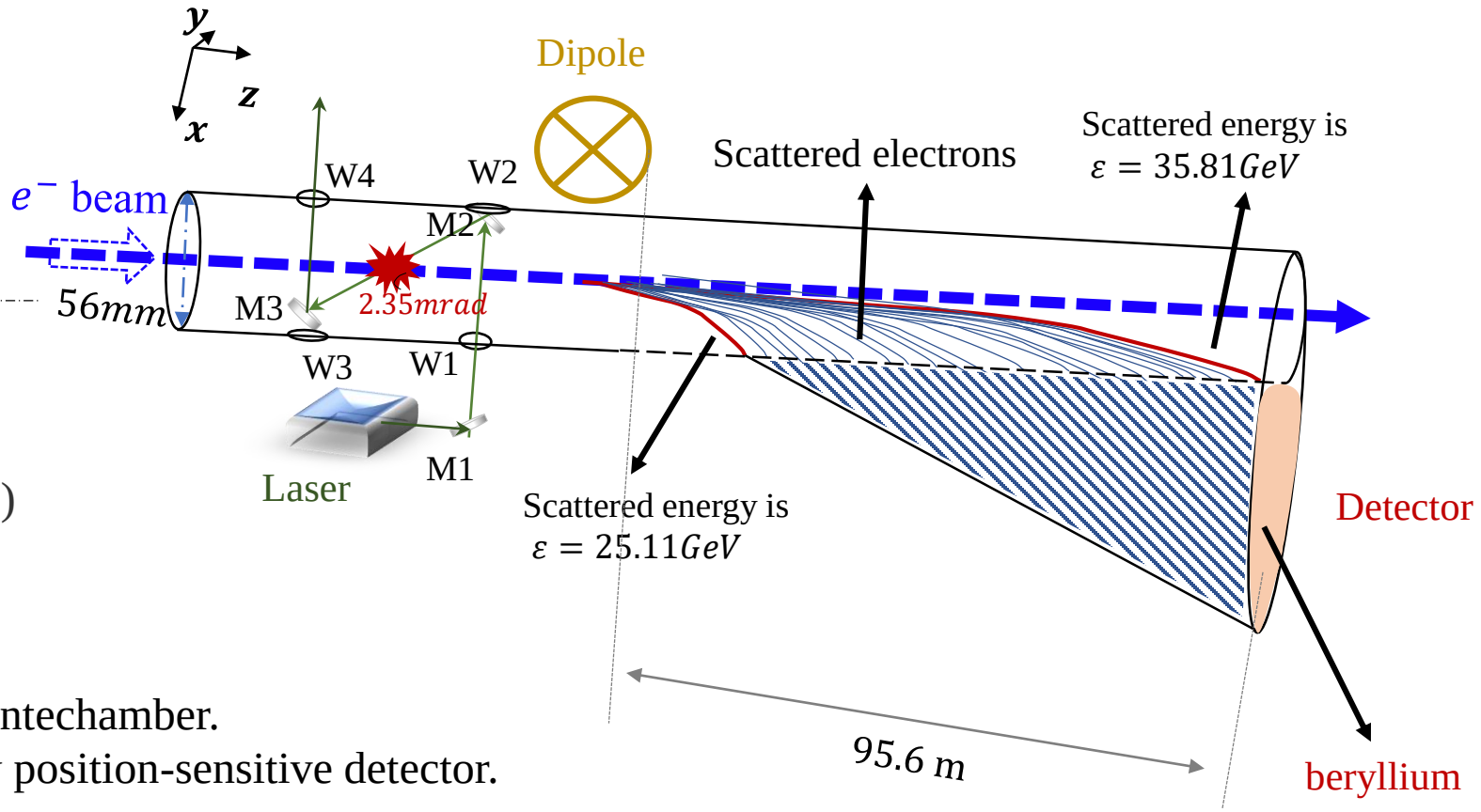
- Free drift section require: no magnet in beampipe.
- Aim: detecting the *asymmetry* spatial distribution of scattered electrons.
- Considering the resolution: free distance 40 meters is enough.
- The feasibility of detecting: recoding scattered electrons outside the beampipe (inner diameter 28mm + thickness 3mm)
  - A drift distance of one hundred meters is necessary

Option 1 for beryllium tube

- 真空盒设计成带有前室的真空盒(antechamber)



cross sectional view 横剖面视图(示意图)

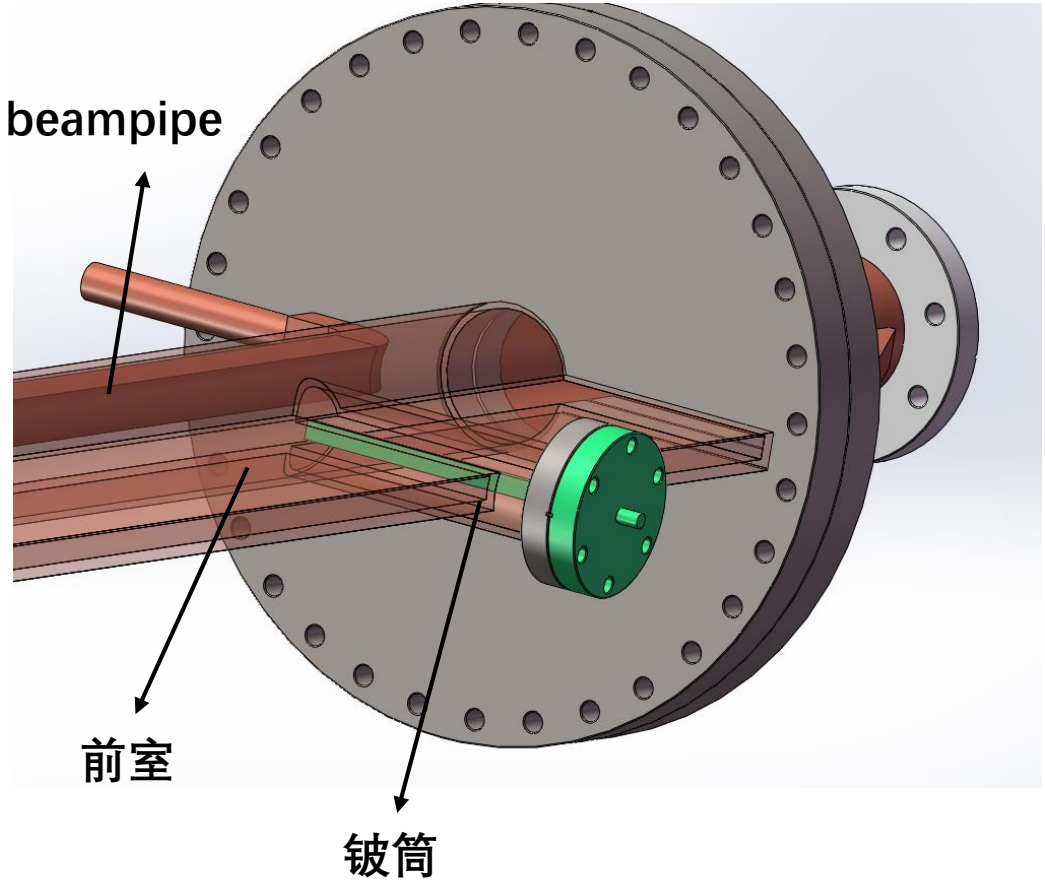


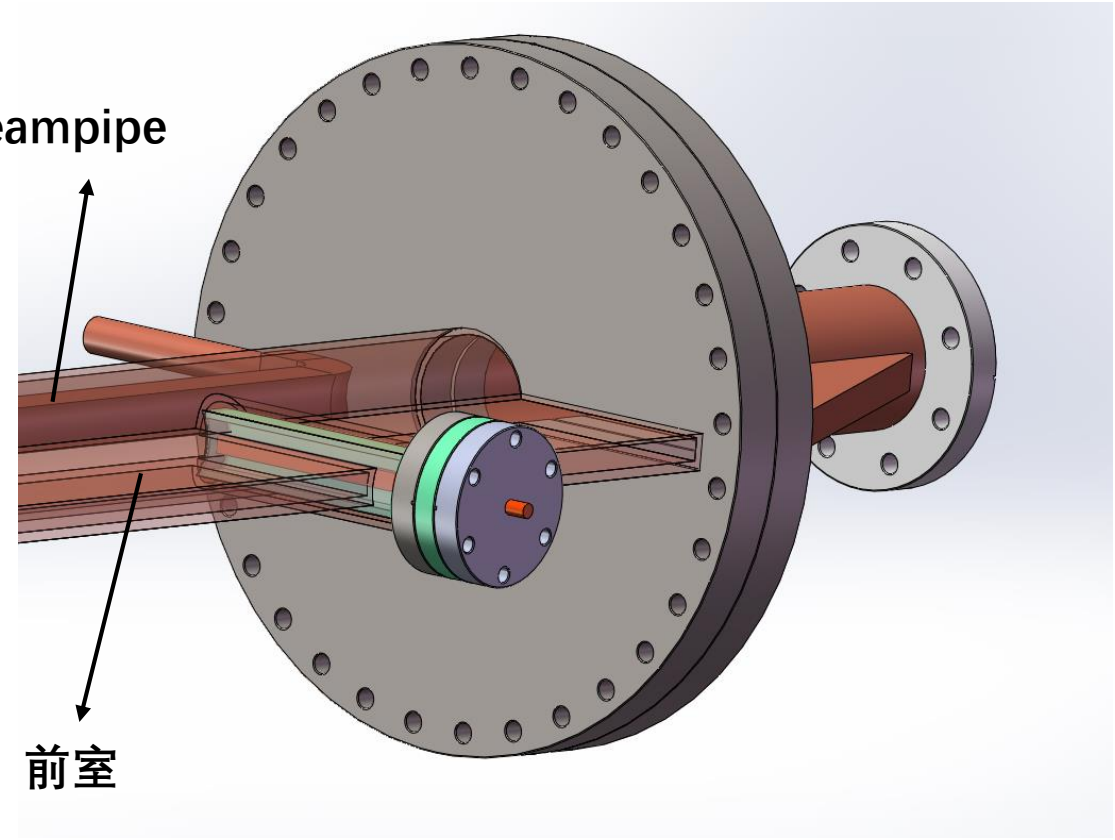
- Scattered electrons propagate in the antechamber.
- 2/3 scattered electron are recorded by position-sensitive detector.
- Free distance about is 95.6m
- Beryllium size: $X_e \times Y_e \approx 62mm \times 1mm$

Option 1 for beryllium tube

Courtesy of Pengcheng Wang

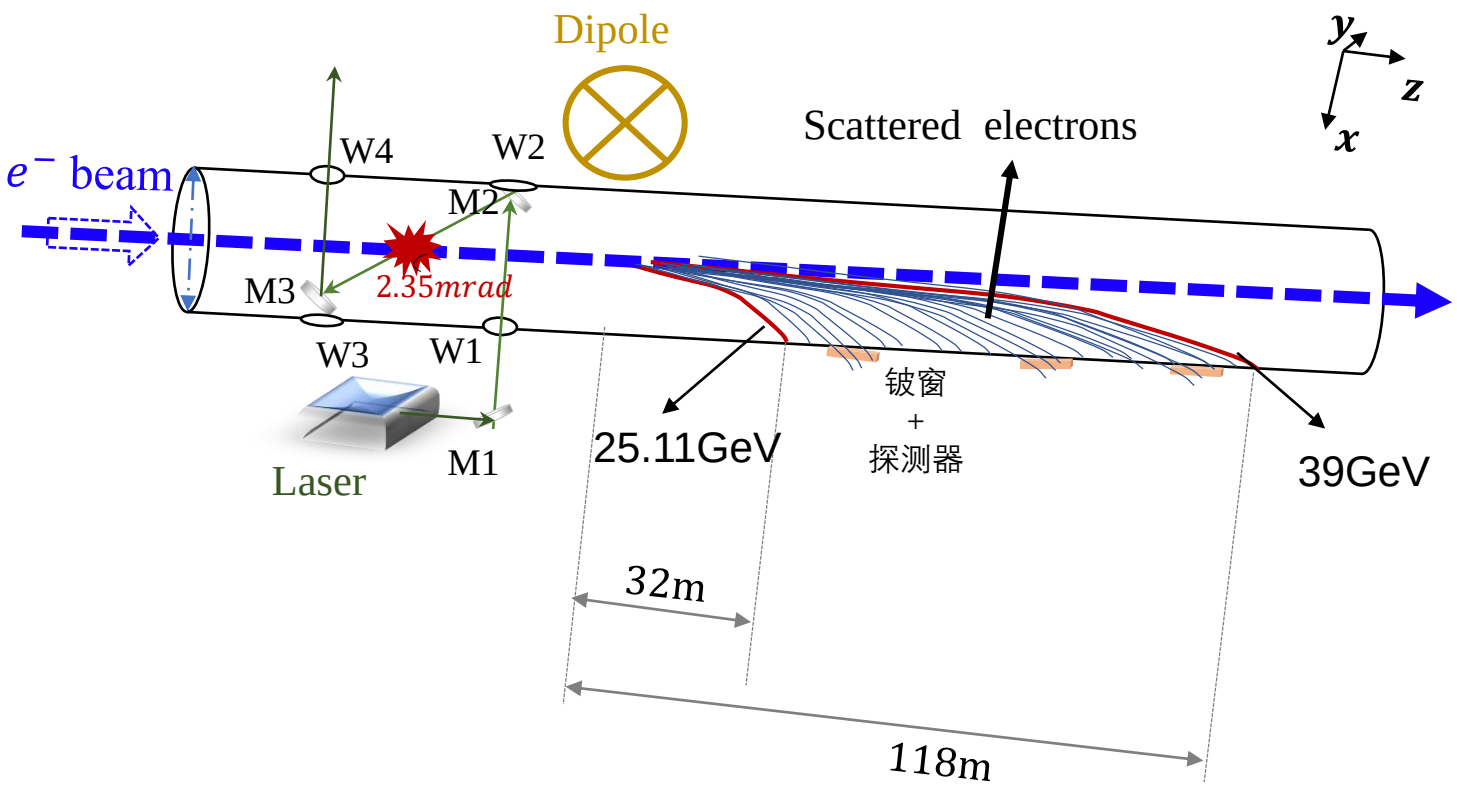
前室真空盒的设计





Option 2 for beryllium tube

- **对于探测器安装方案：**



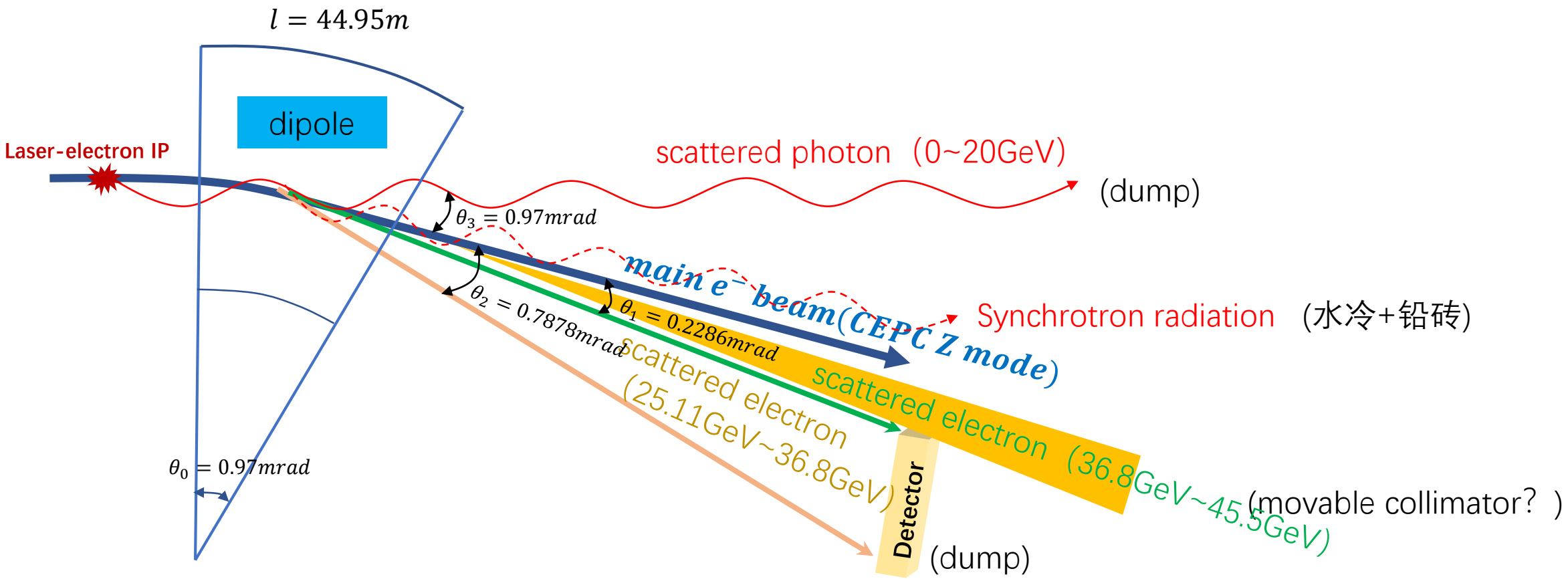
- 在束流管壁外分几个位置贴探测器

Summary

- Accomplished:
  - Compton polarimeter is an optional method to measure beam transverse polarization.
  - non-invasive and can accurately and rapid monitor the transverse polarization.

- Next:
  - Two options for **beampipe** and **beryllium tube**
  - Considering the CEPC lattice
  - More detailed systematic uncertainties need to be estimated
  - Detector simulation
  - Radiation & Shield of the particles
  - ……

Back-up



讨论散射电子/散射光子的吸收装置:

- 散射光子能量区间：$0\sim20GeV$
- 同步辐射:
- 散射电子（被探测器接受）：$25.11GeV\sim36.8GeV$
- 散射电子（未被探测器接受的）：$36.8GeV\sim45.5GeV$

Synchrotron radiation of CEPC Z mode

$$P[W/m] = 14.08\frac{45.5^4 \times 461}{(44.95m/0.97mrad)^2} = 12.95[W/m]$$

$$E_c[keV] = 0.665BE^2 = 2.218\frac{45.5^3}{44.95m/0.97mrad} = 4.5[keV]$$

$$\lambda_c[m] = 18.847\frac{1}{BE^2} = 18.847\frac{1}{0.00327 * 45.5^2} = 2.78 \times 10^{-10}[m]$$

大于特征波长和小于特征波长的光子总辐射能量相等