electron Beam Polarimetry

Ciprian Gal

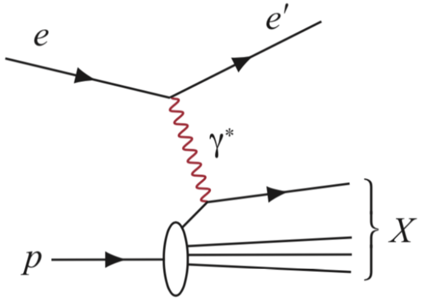
With loads of borrowed materials from Dave Gaskell, Allison Zec and others

References

- CFNS Workshop on Beam Polarization and Polarimetry
  - https://indico.bnl.gov/event/7583/
- EICUG Working Group on Polarimetry and Ancillary Detectors (luminosity monitor)
  - https://indico.bnl.gov/category/280/
- Precision electron beam polarimetry for next generation nuclear physics experiments
  - *Int.J.Mod.Phys.E* 27 (2018) 07, 1830004, https://doi.org/10.1142/S0218301318300047
- "Conceptual Design Report of a Compton Polarimeter for Cebaf Hall A", https://hallaweb.jlab.org/compton/Documentation/Technical/1996/proposal.ps.gz

Structure of the lectures

- Name: Ciprian Gal
- Interesting fact about yourself: ran an experiment on the ESA parabolic flight
- Favorite EIC measurement: inclusive measurements leading to the spin decomposition



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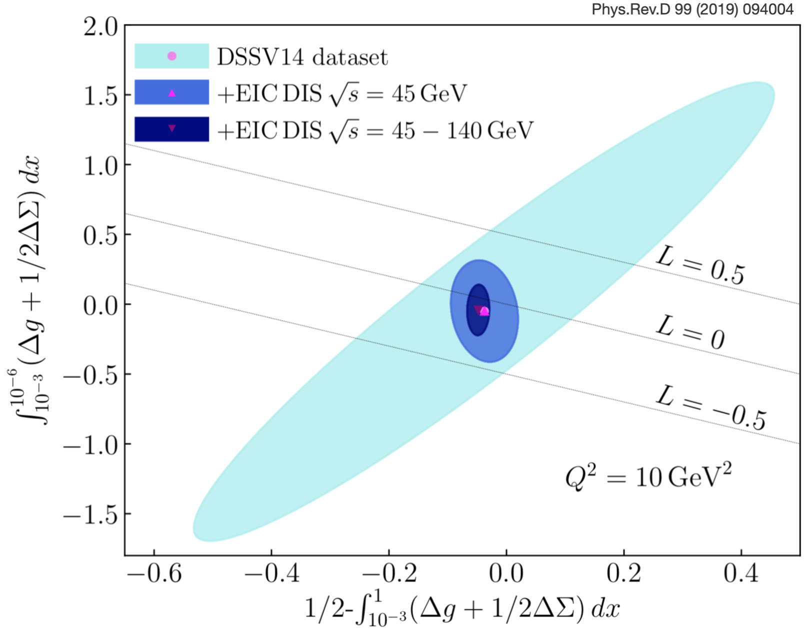

What is bread and butter measurement at the EIC?

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Asymmetry

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How does polarization uncertainty affect your measurement?

Polarization impact on final uncertainty

$$A_{\parallel} = \frac{1}{P_e P_h}\left[\frac{N^{++} - RN^{+-}}{N^{++} + RN^{+-}}\right]$$

Using the equation for an asymmetry evaluate what the level of uncertainty comes from polarization measurement uncertainty (feel free to use pen and paper). Print out this uncertainty for an asymmetry $A = 0.05$ a polarization value of 80% and an absolute polarization uncertainty of 3%. What is the relative uncertainty on the asymmetry?

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In [2]:

```
A = 0.05
P = 0.8
dP = 0.03
dA = A*dP/P
print("dA = ",dA)
print("dA/A = ", dA/A*100, "%")
```

```
dA =  0.001875
dA/A =  3.75 %
```

How to measure polarization?

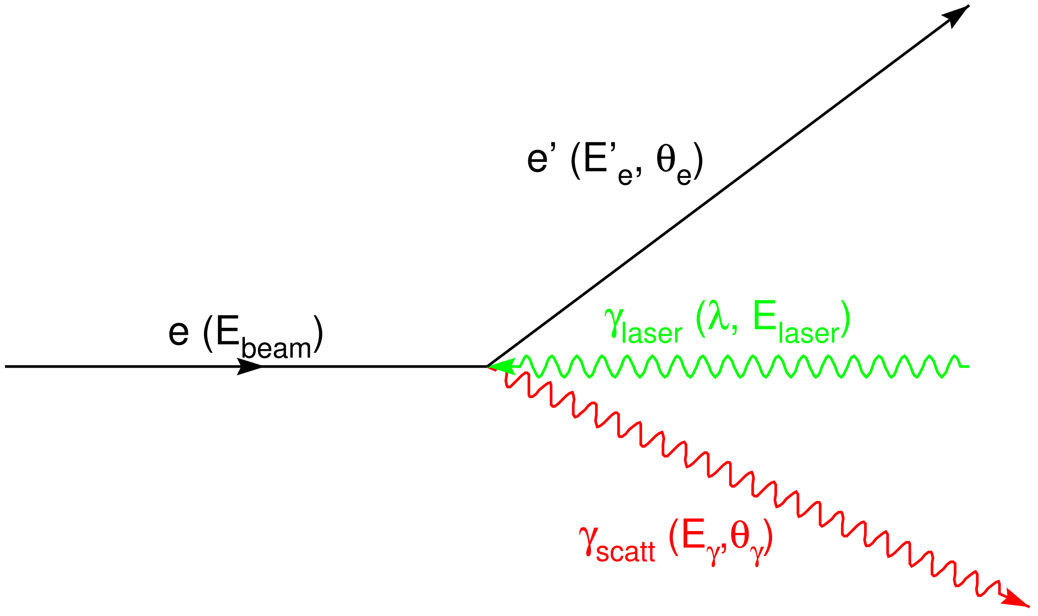
How to measure polarization?

$$A_{\text{measured}} = P_{\text{beam}} A_{\text{effective}}$$

- Polarization measurements rely on precisely known physics processes

Compton scattering

Compton scattering



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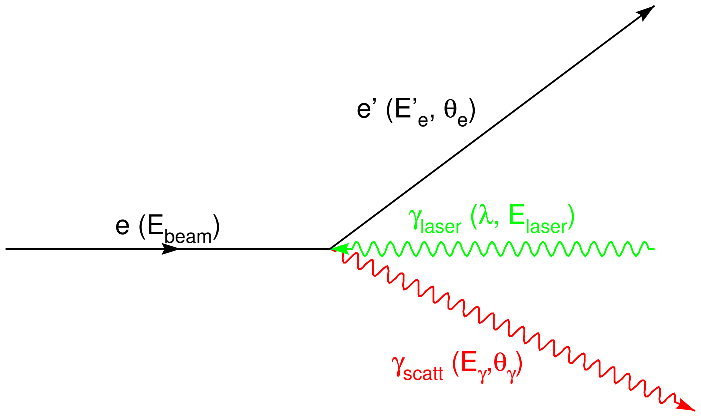
Compton scattering

- The analyzing power ($A_{effective}$) for Compton scattering is precisely known since it's a QED process
- Advantages of measurement
  - Monitor polarization in parallel to data taking
  - Low systematics (can control laser polarization very well)
  - Machine setup requires a fast relative polarimeter
- Works for different beam energies



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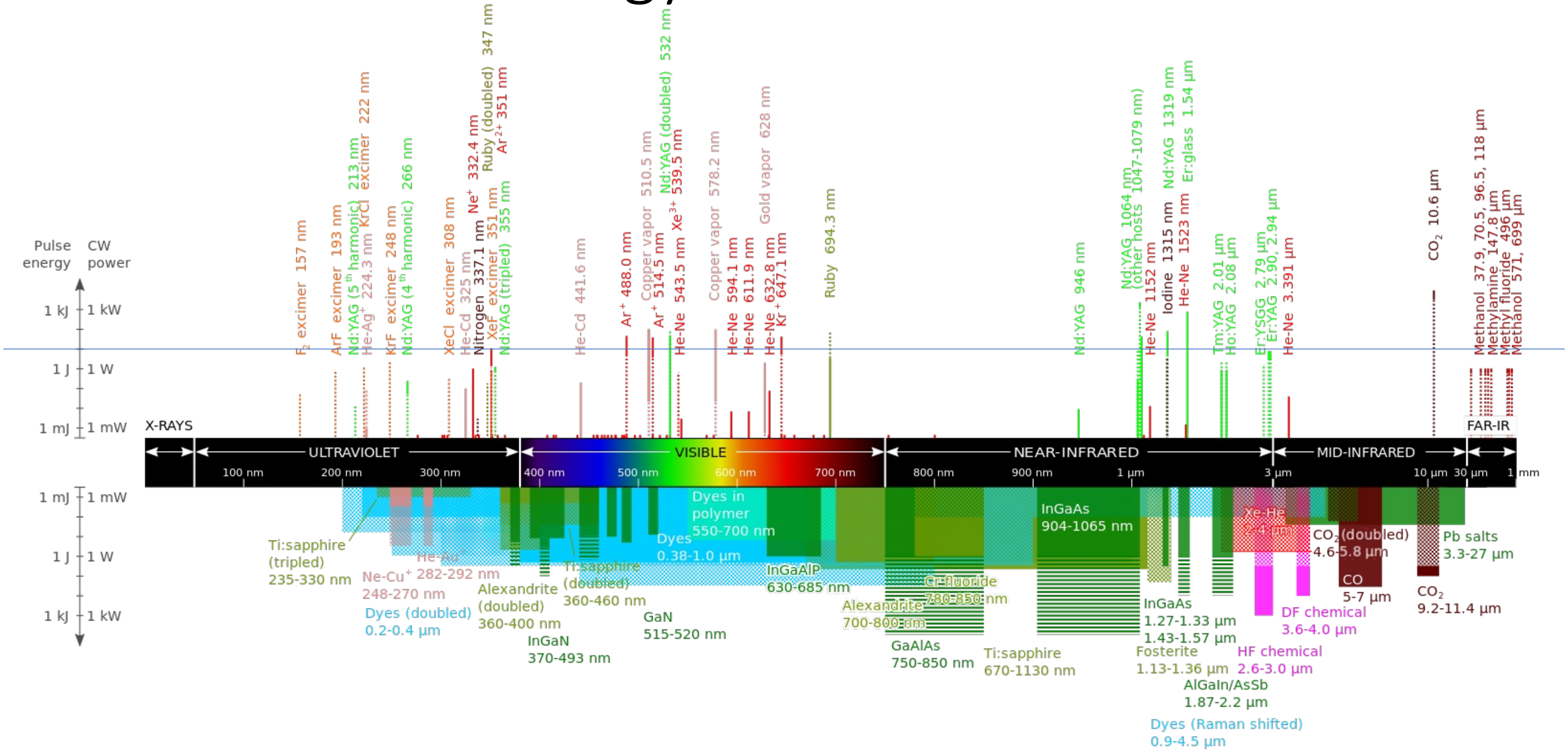
What should the energy of the laser be?



Laser energy

Calculate the energy of a 532nm photon in units of MeV

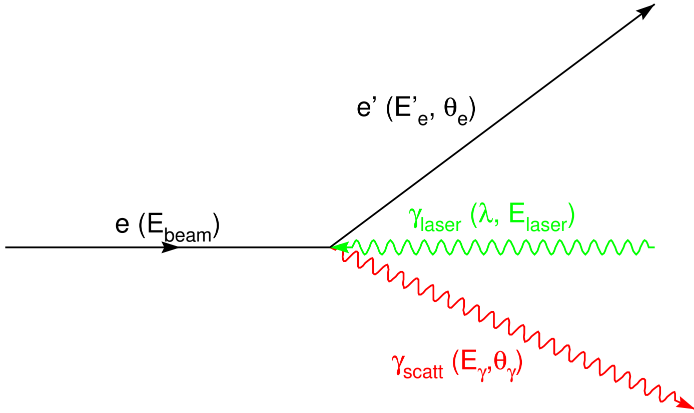
Laser energy

Calculate the energy of a 532nm photon in units of MeV

```
hbarc = 1.9732858E-11
pi = 3.141592653589793
laser_lambda = 532e-7
E_laser = hbarc*2*pi/laser_lambda
print("photon energy = ",E_laser)
```

```
photon energy =  2.3305489371101722e-06
```

Compton scattering basics

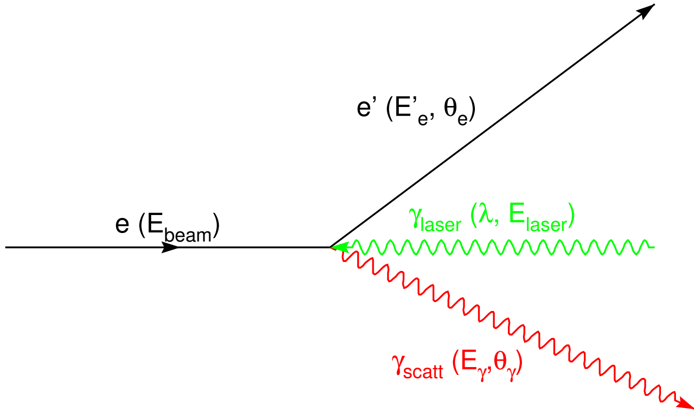


$$\gamma = E_{beam}/m_{electron}$$

$$E_\gamma \approx E_{\text{laser}} \frac{4a\gamma^2}{1 + a\theta_\gamma^2\gamma^2}$$

$$a = \frac{1}{1 + 4\gamma E_{\text{laser}}/m_e}$$

Compton scattering basics



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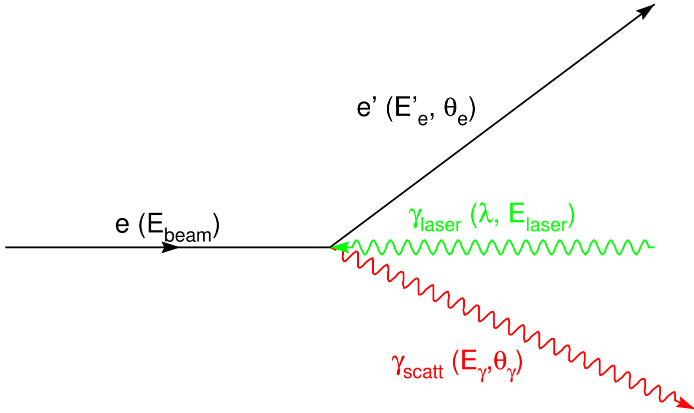

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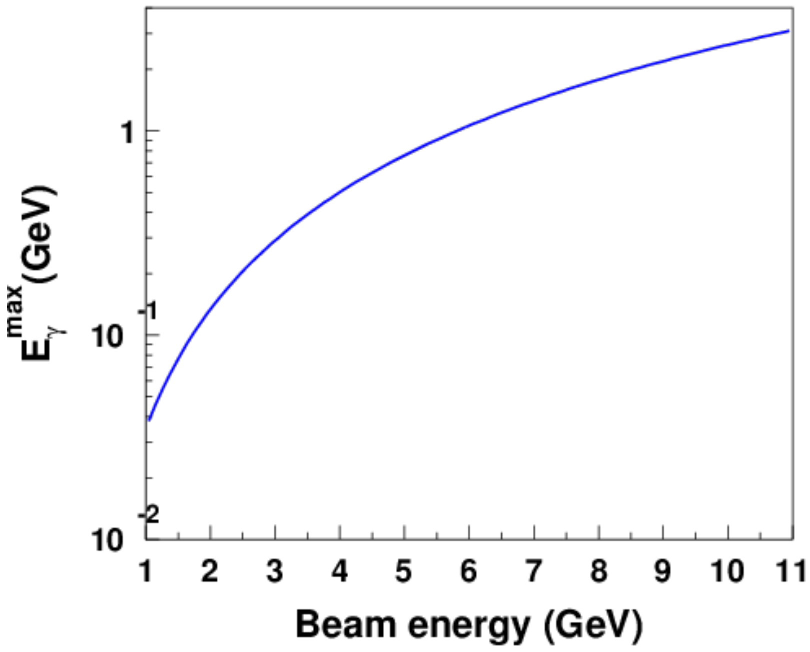

Maximum backscattered photon energy at θ=0 degrees (180 degree scattering)

<u>For green laser (532 nm):</u>

→ E_γ^{max} ~ 34.5 MeV at E_{beam}=1 GeV

→ E_γ^{max} = 3.1 GeV at E_{beam}=11 GeV

Angle at which $E_\gamma = E_\gamma^{max}/2$

$$\theta_{\gamma 1/2} = \frac{1}{\gamma\sqrt{a}}$$

Scattered photon cone

Calculate the angle for which the scattered photon energy is half of the maximum energy:

In [5]:
```python
Theta_half = np.sqrt(1/(a*gamma**2))
print("E_g_max/2 angle (deg) = ",Theta_half*180/pi)
```

```
E_g_max/2 angle (deg) =  0.006356700858973076
```

Calculate the radial position of this photon 30 meters from the interaction region:

In [6]: