Compton polarimetry for the EIC

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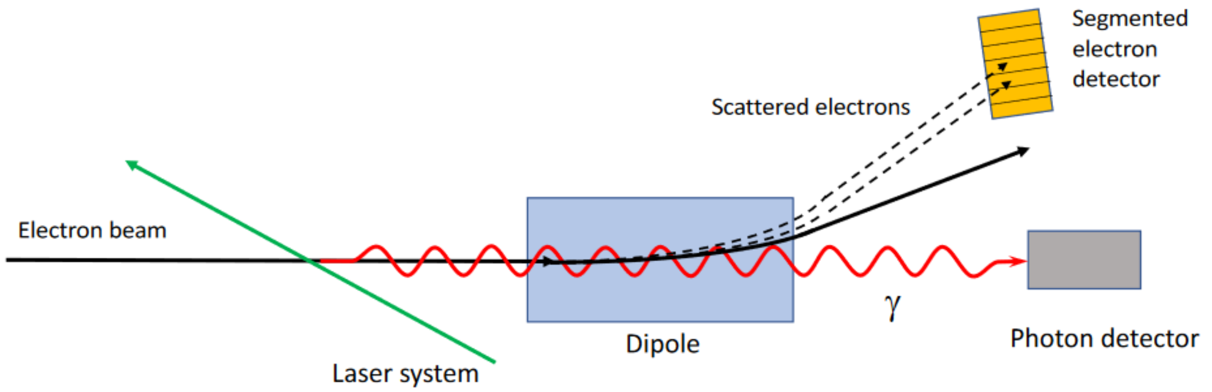
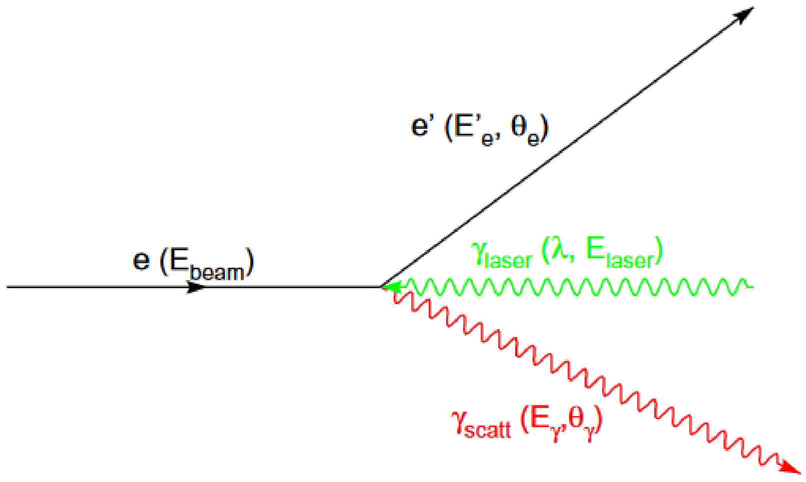
Compton polarimetry



Polarimeter	Energy	Sys. Uncertainty
CERN LEP*	46 GeV	5%
HERA LPOL	27 GeV	1.6%
HERA TPOL*	27 GeV	2.9%
SLD at SLAC	45.6 GeV	0.5%
JLAB Hall A	1-6 GeV	1-3%
JLab Hall C	1.1 GeV	0.6%

- Has seen extensive use in collider and fixed target facilities
  - Recent results have reached below 1% systematics at low energies (with electron measurements)
- It is an ideal candidate because of the non-destructive nature of the measurement



Compton polarimetry: measurement types

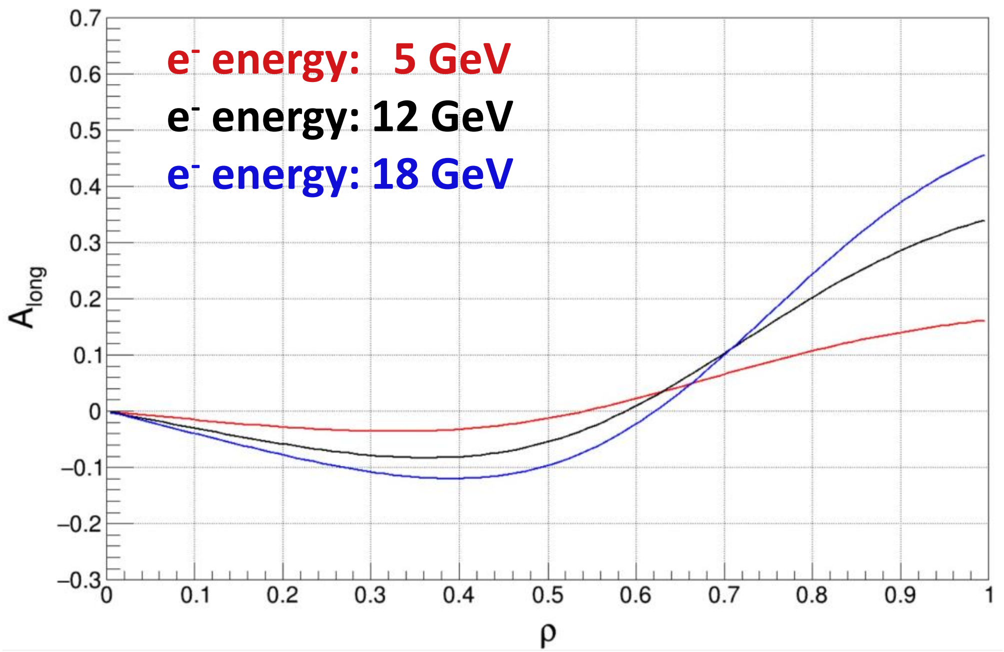
A. Single-photon mode
   - Detection event by event; improved precision through fit to energy distribution
   - Ideal for low background environments

B. Multi-photon mode (integrating)
   - The number of detected photons/electrons is measured
   - Will increase the S/B for situations when there is significant backgrounds

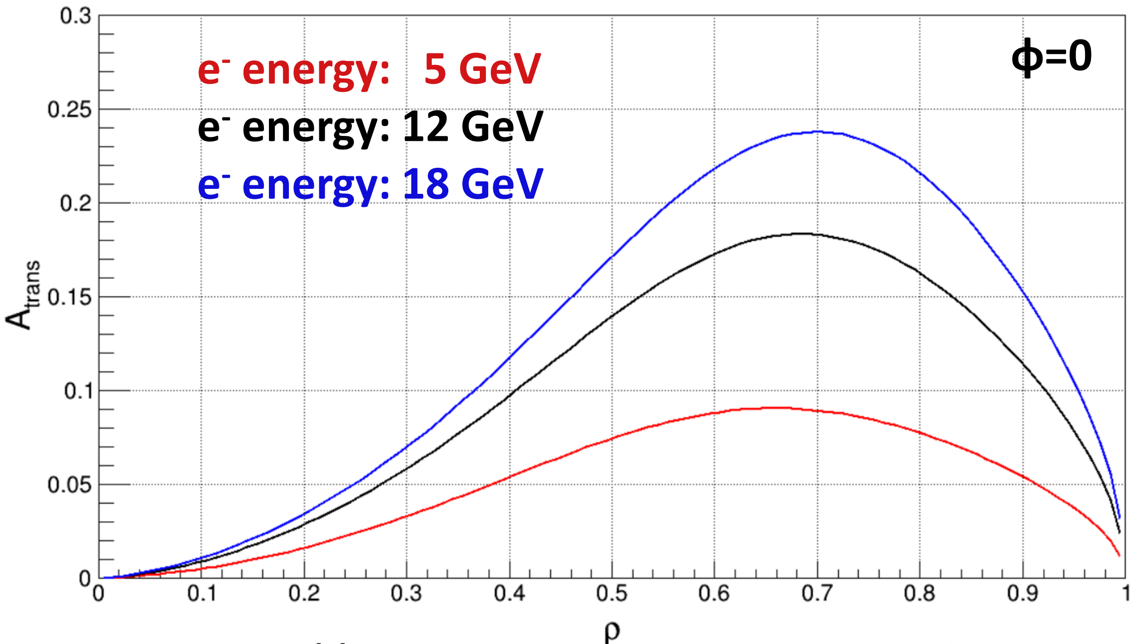
C. Energy weighted multi-photon mode (integrating)
   - The energy of the scattered particles has a linear relationship with measured quantity

Asymmetries for longitudinal and transverse polarimeters

$$A_{\text{long}} = \frac{\sigma^{++} - \sigma^{-+}}{\sigma^{++} + \sigma^{-+}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}(1-\rho(1+a))\left[1 - \frac{1}{(1-\rho(1-a))^2}\right]$$



$$A_{\text{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a)\frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))}\right]$$

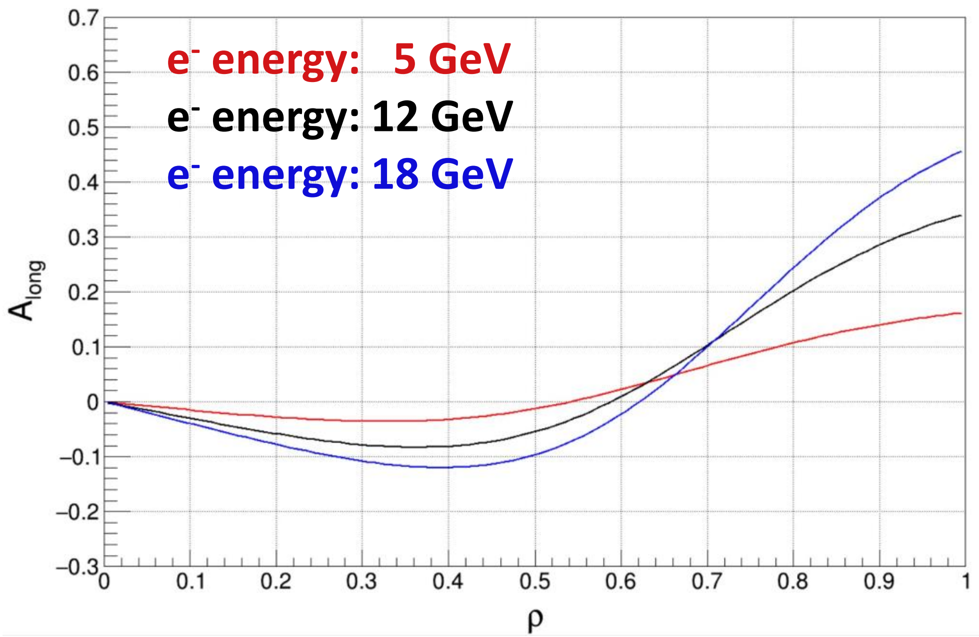


****Calculations based on 532nm laser system**

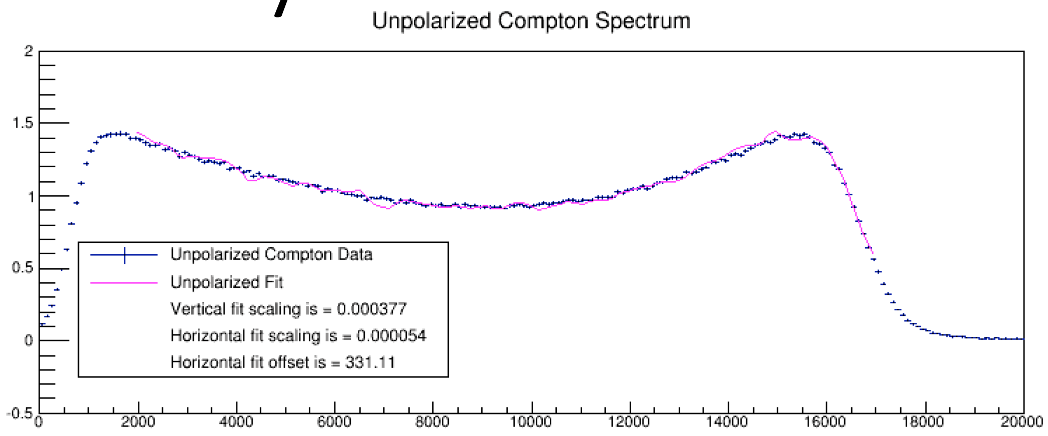
- For both the longitudinal and transverse polarimetry measurements at the at the energies of interested for the EIC the analyzing powers are significant

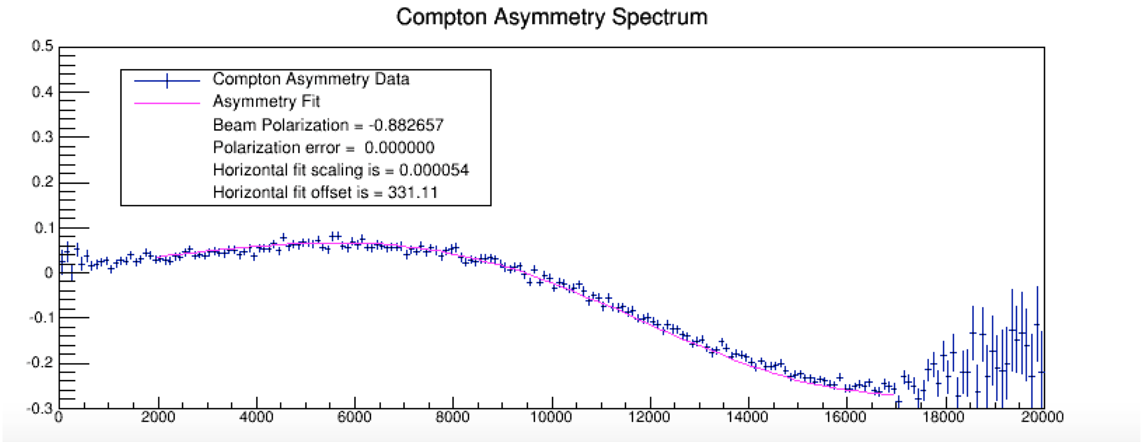
Longitudinal Compton polarimetry

$$A_{\text{long}} = \frac{\sigma^{++} - \sigma^{-+}}{\sigma^{++} + \sigma^{-+}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}(1-\rho(1+a))\left[1 - \frac{1}{(1-\rho(1-a))^2}\right]$$



- Photon measurements can have large systematics due to detector response
- Best measurements achieved with electron detection
- At higher energies – spectrum threshold less important

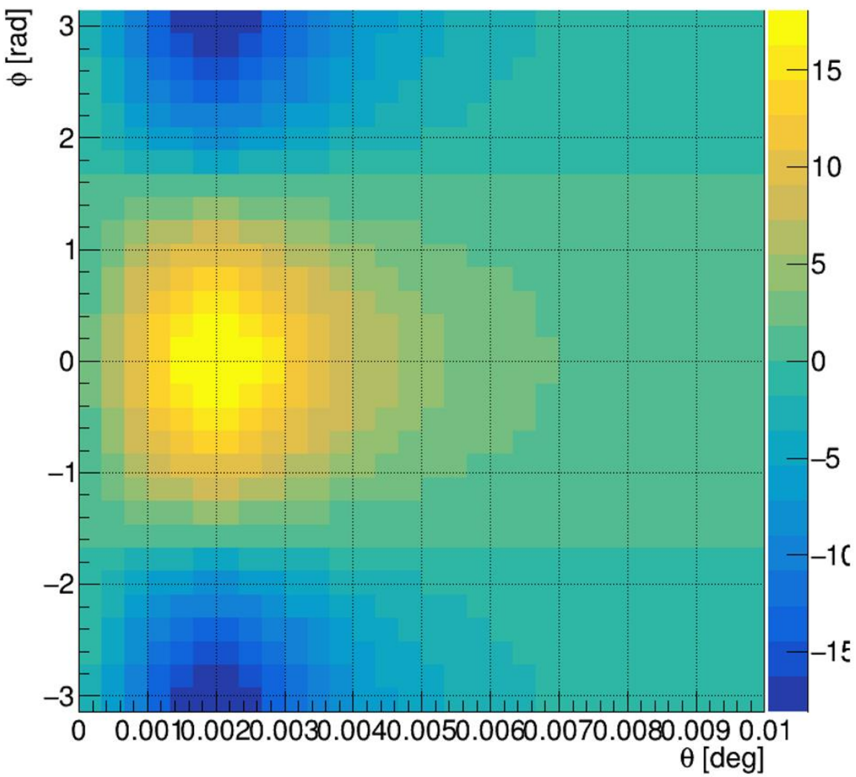




HERA FP cavity-based LPOL achieved 0.9-1.1% precision with differential measurements in single-photon mode @ 27 GeV
→ Unlikely similar precision can be achieved at lowest energies envisioned for EIC

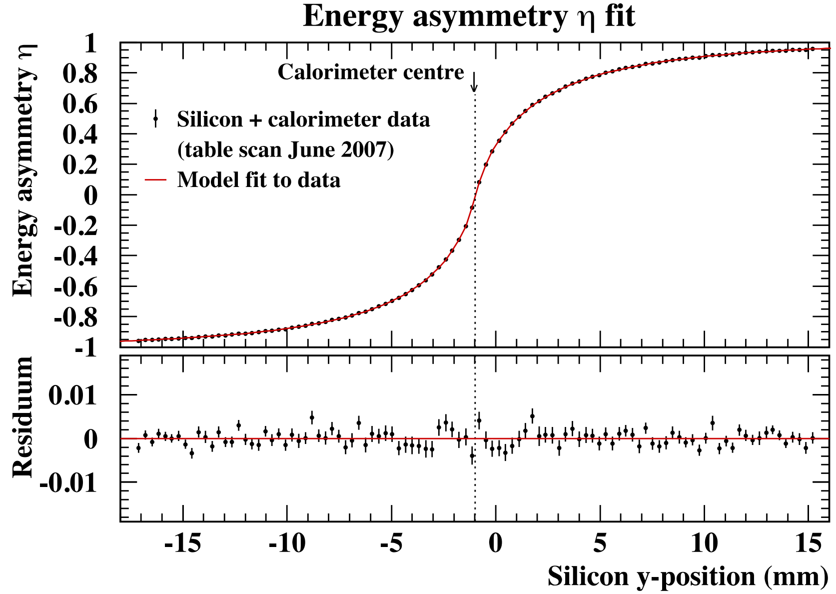
Transverse Compton polarimetry

$$A_{\mathrm{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a) \frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))} \right]$$



- Measurements are more challenging because you are looking at a position asymmetry

$$\eta = \frac{E_U - E_D}{E_U + E_D}$$



B. Sobloher et al, DESY-11-259 , arXiv:1201.2894

- HERA used a sampling calorimeter with top and bottom optically isolated: → Polarization measured via up-down energy asymmetry
- Strip detectors provide can be used to help calibrate the detector response
- With careful polarimeter design, high precision transverse measurements should be achievable

eRHIC specifications

- At 18 GeV bunches will be replaced every 6 min -> polarimetry measurement needs to happen in a much shorter time span
- The amount of electrons per bunch is fairly small ~24 nC → will need bright laser beam to obtain needed luminosity
- Distance between buckets is ~10ns → bunch by bunch measurement cannot be done with a CW laser without super fast detectors

Table 1: Maximum Luminosity Parameters

Parameter	***hadron***	***electron***
Center-of-Mass Energy [GeV]	104.9	
Energy [GeV]	275	10
Number of Bunches	1320	
Particles per Bunch [10^{10}]	6.0	15.1
Beam Current [A]	1.0	2.5
Horizontal Emittance [nm]	9.2	20.0
Vertical Emittance [nm]	1.3	1.0
Hor. β-function at IP β_x^* [cm]	90	42
Vert. β-function at IPβ_y^* [cm]	4.0	5.0
Hor./Vert. Fractional Betatron Tunes	0.3/0.31	0.08/0.06
Horizontal Divergence at IP [mrad]	0.101	0.219
Vertical Divergence at IP [mrad]	0.179	0.143
Horizontal Beam-Beam Parameter ξ_x	0.013	0.064
Vertical Beam-Beam Parameter ξ_y	0.007	0.1
IBS Growth Time longitudinal/horizontal [hours]	2.2/2.1	-
Synchrotron Radiation Power [MW]	-	9.18
Bunch Length [cm]	5	1.9
Hourglass and Crab Reduction Factor	0.87	
Luminosity [10^{34}cm-2sec-1]	1.05	

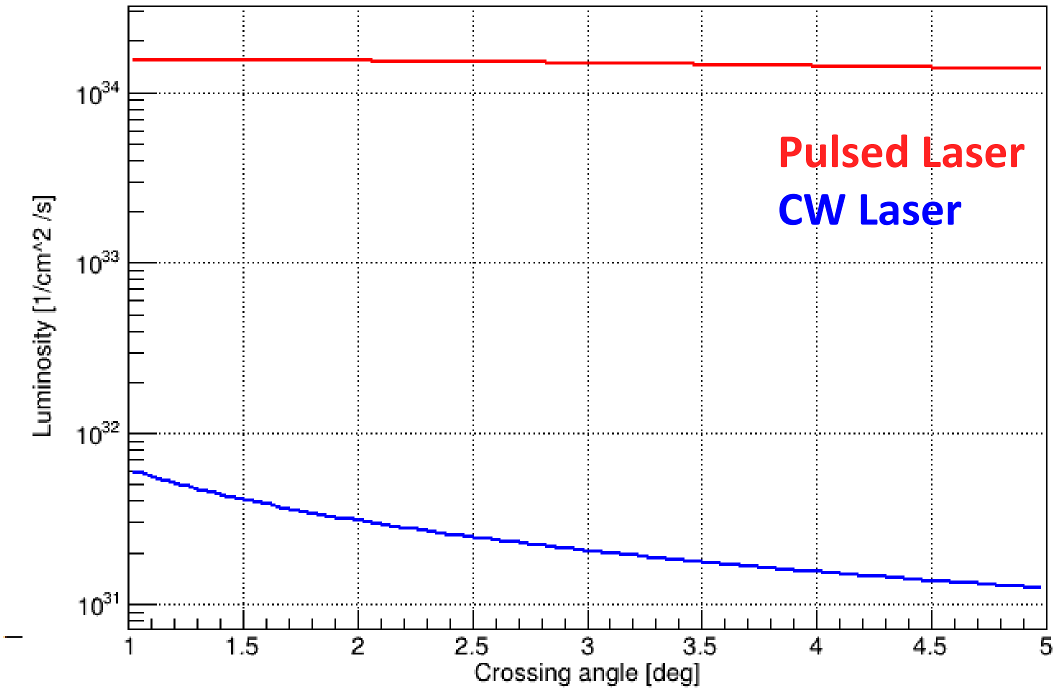
CW vs pulsed laser luminosity

- CW lasers could provide relative rapid measurements for average polarization of all bunches in ring
  - Bunch-by-bunch measurements challenging due to relatively small bunch spacing
- Pulsed system would allow straightforward identification of individual bunches AND improved luminosity
- Looking at a single bunch (with a beam frequency of ~78kHz) the luminosity for the same average power in the cavity (1kW) as a function of crossing angle shows a significant advantage for the pulsed cavity

- The conceived laser system has a repetition rate of 10MHz
  - Allow for simultaneous measurement of ~120 bunches, but leaving 100 ns between collisions for detector response
  - Shifting laser phase would allow measurement of all bunches

$$\mathcal{L}_{\mathrm{CW}} \approx \frac{1+\cos(\alpha_C)}{\sqrt{2\pi}\sin(\alpha_C)} \frac{I_e}{e} \frac{P_L\lambda}{hc^2} \frac{1}{\sqrt{\sigma_e^2+\sigma_\gamma^2}}$$

$$\mathcal{L}_{\mathrm{pulsed}} \approx \frac{1+\cos(\alpha_C)}{2\pi\sin(\alpha_C)} \frac{I_e}{e} \frac{c}{f_{beam}} \frac{P_L\lambda}{hc^2} \frac{1}{\sqrt{\sigma_e^2+\sigma_\gamma^2}} \left(\sigma_{e,z}^2+\sigma_{\gamma,z}^2+\frac{\sigma_e^2+\sigma_\gamma^2}{\sin^2(\alpha_c/2)}\right)^{-}$$

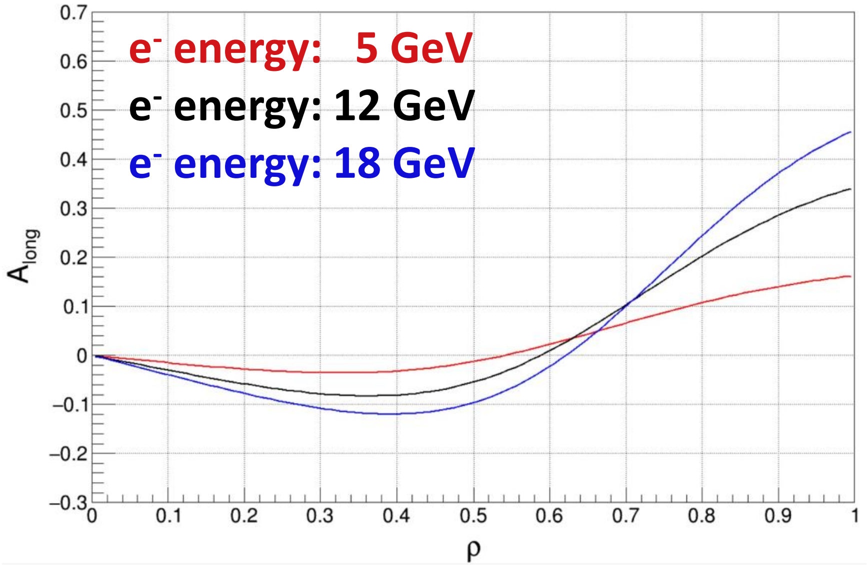


Time estimations: longitudinal

$$t_{meth} = \left(\mathcal{L}\ \sigma_{\mathrm{Compton}}\ \mathrm{P_e^2 P_\gamma^2} \left(\frac{\Delta \mathrm{P_e}}{\mathrm{P_e}} \right)^2 \mathrm{A^2_{meth}} \right)^{-1}$$

A_{meth}

Single-photon	**Integrating**	**Energy Integrating**
$\langle \mathrm{A}^2 \rangle$	$\langle \mathrm{A} \rangle^2$	$\dfrac{\langle \mathrm{E} \cdot \mathrm{A} \rangle^2}{\langle \mathrm{E}^2 \rangle}$



beam energy [GeV]	$\langle A^2_{\mathrm{long}} \rangle$	t[s]	$\langle A_{\mathrm{long}} \rangle^2$	time [ms]	$\frac{\langle \mathrm{E} \cdot \mathrm{A} \rangle^2}{\langle \mathrm{E}^2 \rangle}$	time [ms]
5	0.0061	29	0.0012	166	0.0022	88
12	0.0244	7	0.0033	69	0.0064	36
18	0.0414	4	0.0041	63	0.0085	30

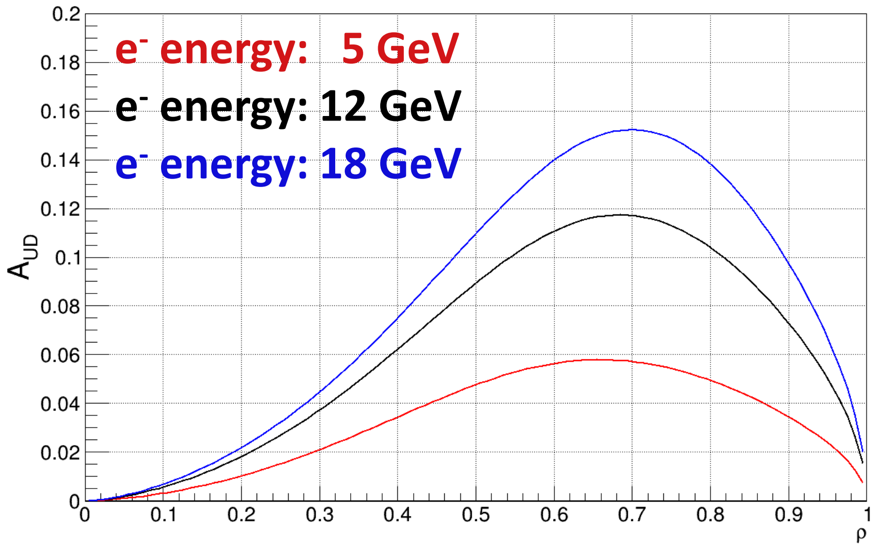
- Differential measurement assumes 1 photon/electron per crossing
  - The power needed for the laser system is approximately 1W
- The integrated method accepts the entire luminosity of the pulsed system (note the change in unit)
- Measurement times for all bunches in ring about 10 times longer

Time estimations: transverse

$$t_{meth} = \left(\mathcal{L} \, \sigma_{\mathrm{Compton}} \; \mathrm{P_e^2 P_\gamma^2} \; \left(\frac{\Delta \mathrm{P_e}}{\mathrm{P_e}} \right)^2 \; \mathrm{A^2_{meth}} \right)^{-1}$$

A_{meth}

Single-photon	**Integrating**	**Energy Integrating**
$\langle \mathrm{A}^2 \rangle$	$\langle \mathrm{A} \rangle^2$	$\dfrac{\langle \mathrm{E} \cdot \mathrm{A} \rangle^2}{\langle \mathrm{E}^2 \rangle}$

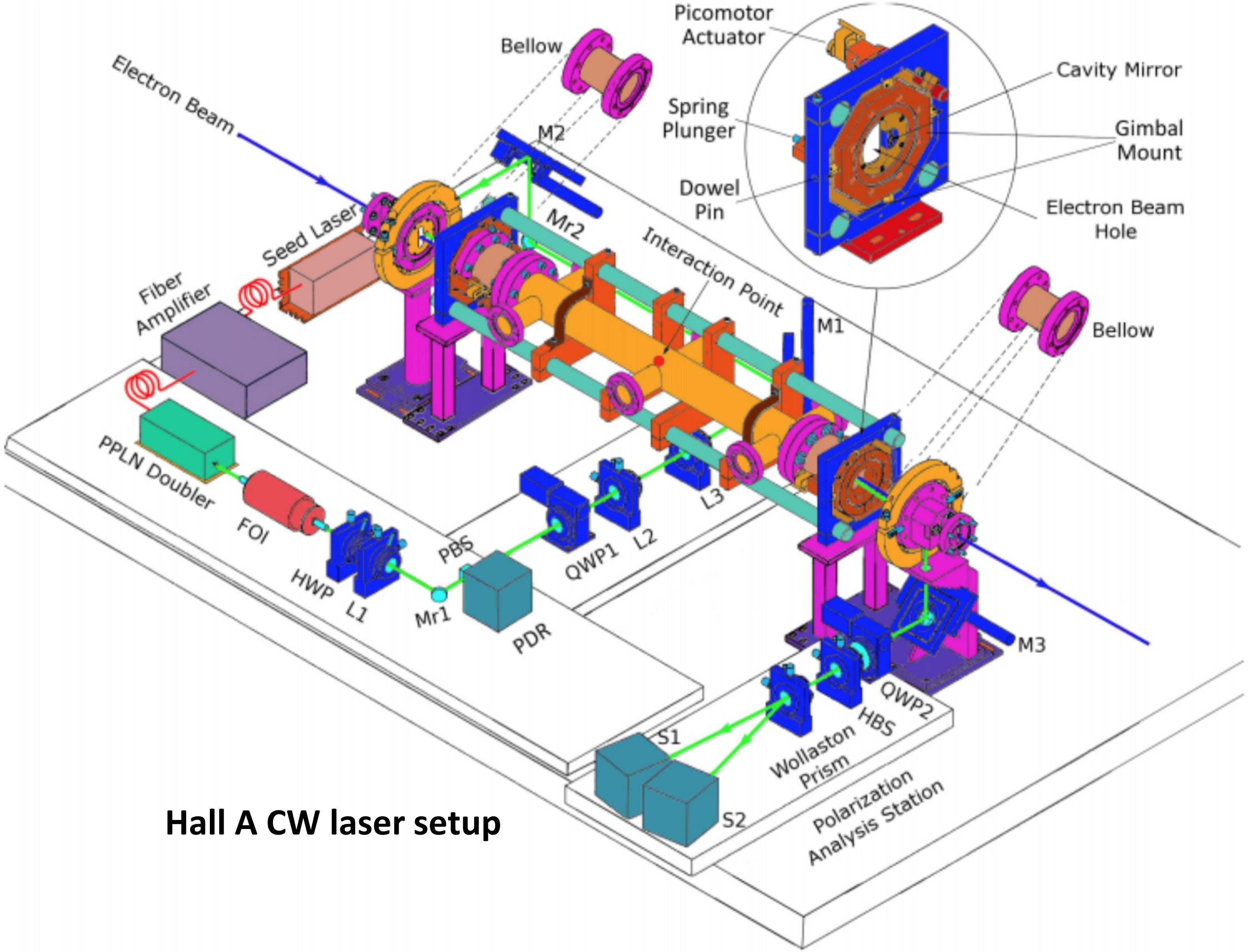


beam energy [GeV]	$\langle A^2_{\mathrm{UD}} \rangle$	t[s]	$\langle A_{\mathrm{UD}} \rangle^2$	time [ms]	$\frac{\langle \mathrm{E} \cdot \mathrm{A} \rangle^2}{\langle \mathrm{E}^2 \rangle}$	time [ms]
5	0.0012	144	0.0008	234	0.0005	352
12	0.0048	365	0.0032	72	0.0019	123
18	0.0080	222	0.0052	49	0.0028	92

- Differential measurement assumes 1 photon/electron per crossing
  - The power needed for the laser system is approximately 1W
- The integrated method accepts the entire luminosity of the pulsed system (note the change in unit)

Proposed R&D

- We'd like to focus this R&D effort on developing a pulsed cavity with a large average power and large frequency
- Additionally we'd like to increase the robustness of the system by having rad-soft items (like seed laser and amplifier) at a large distance from the cavity itself
- Ideally we'd be able to test the system at CEBAF in hall A or hall C



Hall A CW laser setup

Laser system development

Initial laser development in lab

- Key Equipment required:
  - *Mode-locked laser*. Fiber amplifier and PPLN crystal also required for green laser.
  - Low-loss mirrors, cavity electronics
  - Some of the above may be borrowed from collaborating institutions

Deployment in beamline

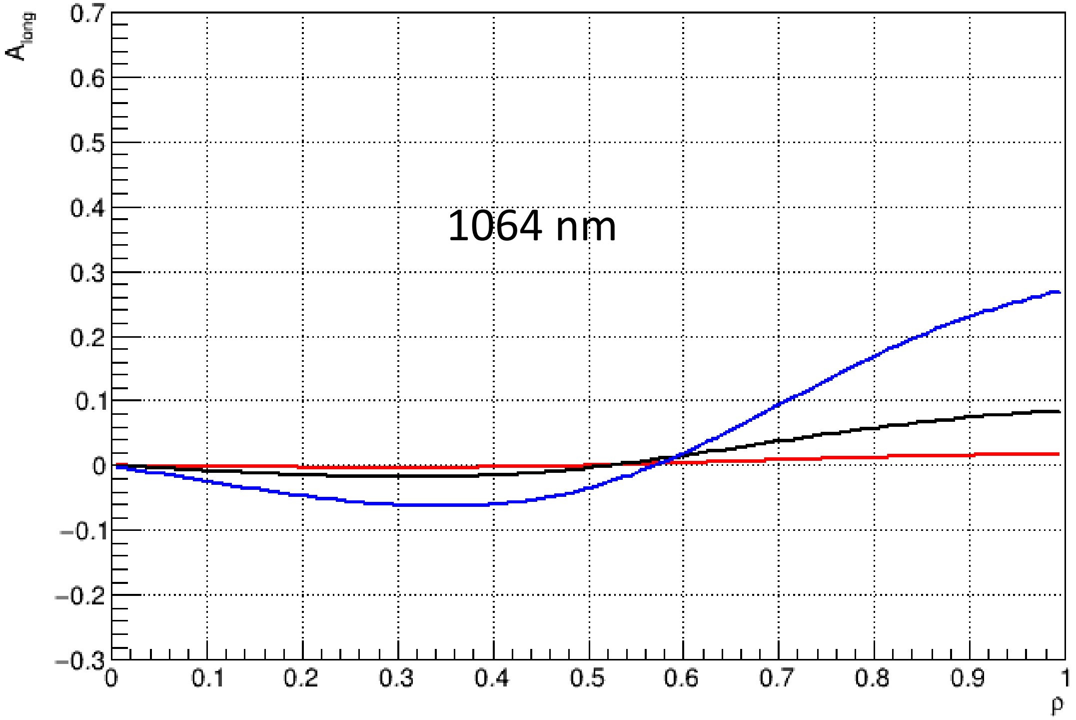
- Could be deployed in either Hall A or C at JLab
- Would require some modification of interaction region/vacuum system
  - Existing system somewhat modular, so modifications could possibly be done relatively cheaply
- Test with beam to verify ability to synchronize laser pulses with beam RF time

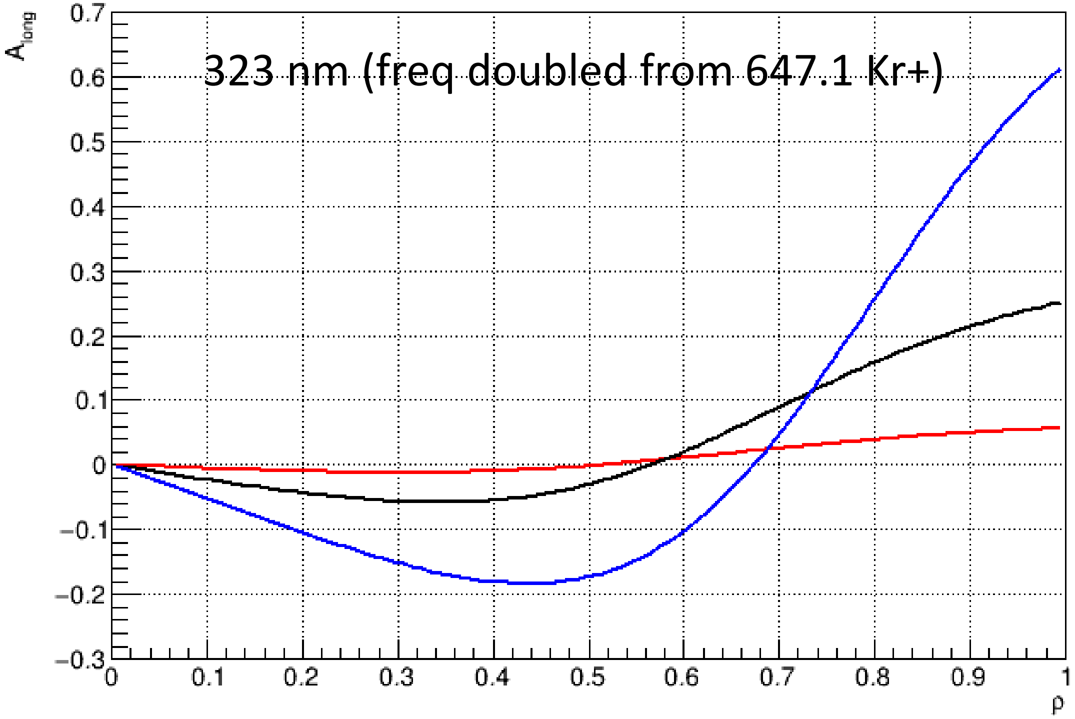
Conclusions

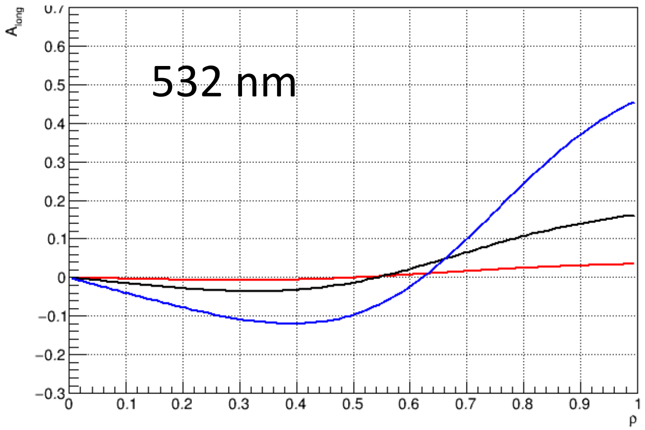
- Pulsed cavity is desirable to be able to make precise polarization measurements of each electron bunch rapidly
- A pulsed laser system allows straightforward measurement of the bunch-by-bunch electron polarization without the need for very fast detectors
- CW Fabry-Perot cavities relatively common in accelerator environment – pulsed cavity requires R&D and testing

Backup

Laser wavelength - power







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

$$E_\gamma^{\rm max} = 4aE_{\rm laser}\gamma^2$$

$$\rho = E_\gamma / E_\gamma^{\rm max}$$

$$A_{\rm long} = \frac{\sigma^{++} - \sigma^{-+}}{\sigma^{++} + \sigma^{-+}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}(1 - \rho(1+a))\left[1 - \frac{1}{(1-\rho(1-a))^2}\right]$$

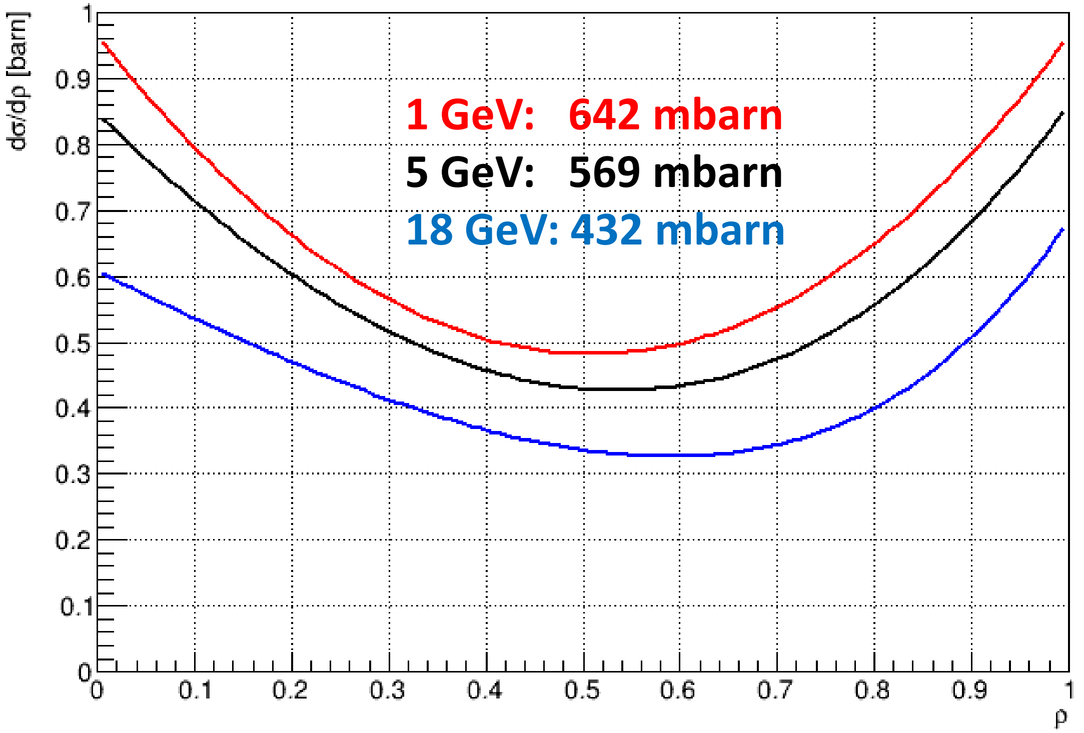
$$a = \frac{1}{1 + 4\gamma E_{\rm laser}/m_e}.$$

Laser power requirements for a CW cavity

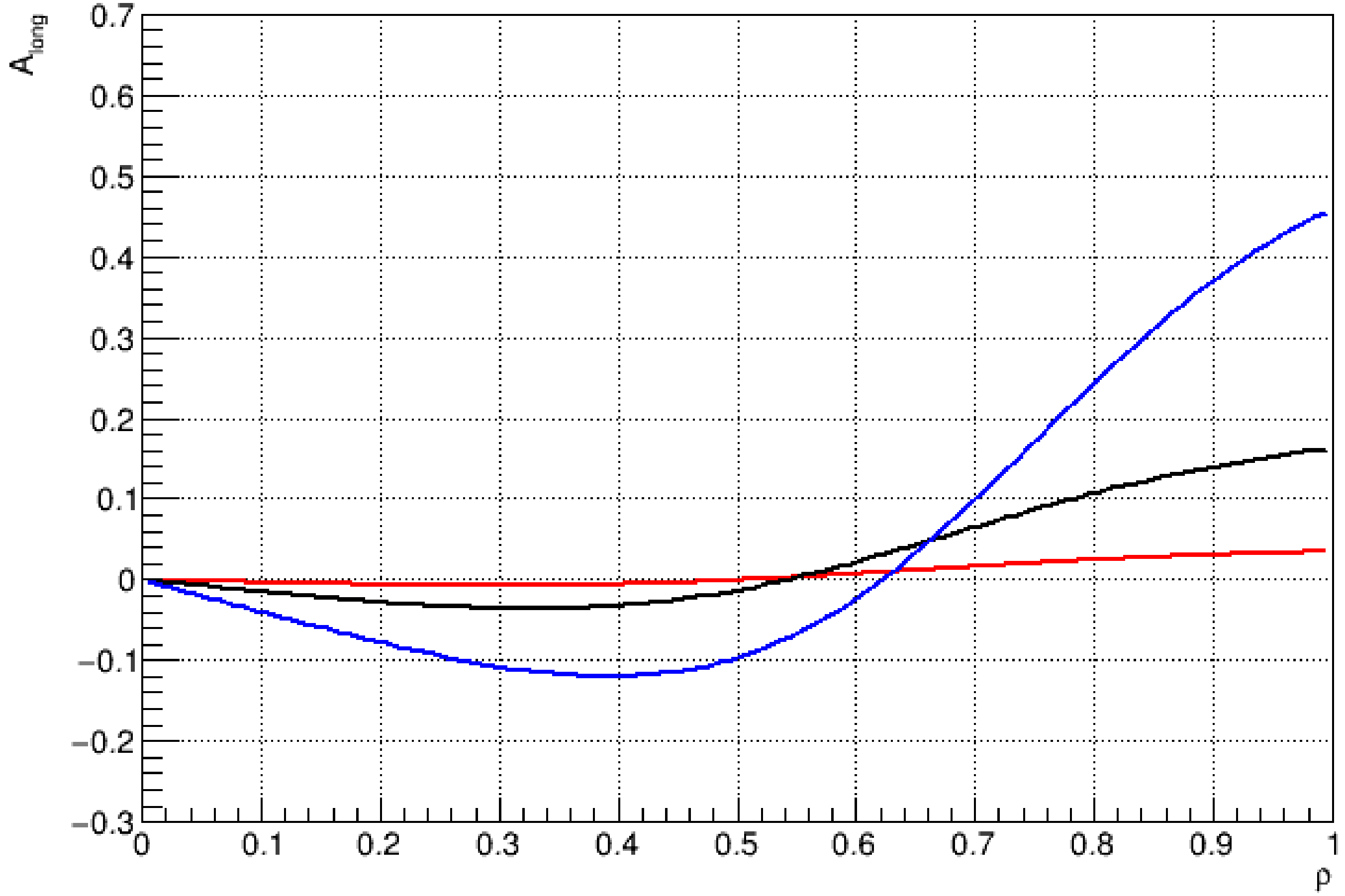
beam energy [GeV]	Unpol Xsec[barn]	$\mathcal{L}$ [1/(barn^{2}s)]	Laser Power [W]
5	0.569	137439	1.1
12	0.482	162139	1.3
18	0.432	180968	1.5

Table 2: Luminosity and laser power needed to achieve measurement times listed in table 4.

Along for 1, 5, 18 GeV (532 nm)

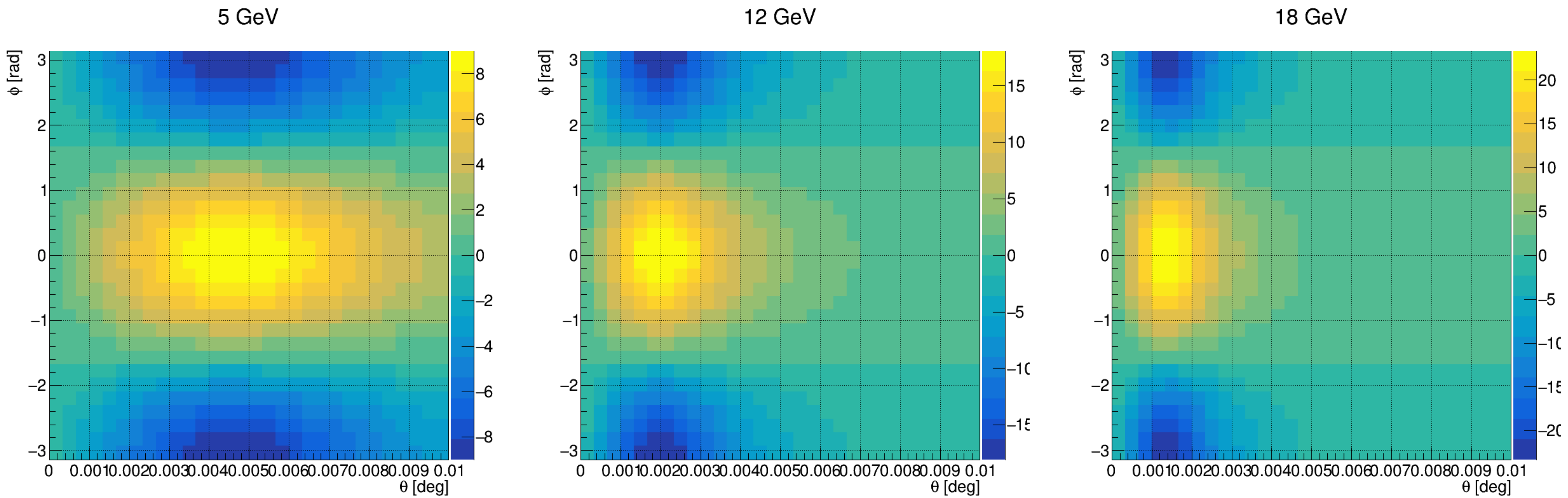


$$\frac{d\sigma}{d\rho} = 2\pi r_o^2 a \left[\frac{\rho^2(1-a)^2}{1-\rho(1-a)} + 1 + \left(\frac{1-\rho(1+a)}{1-\rho(1-a)} \right)^2 \right],$$



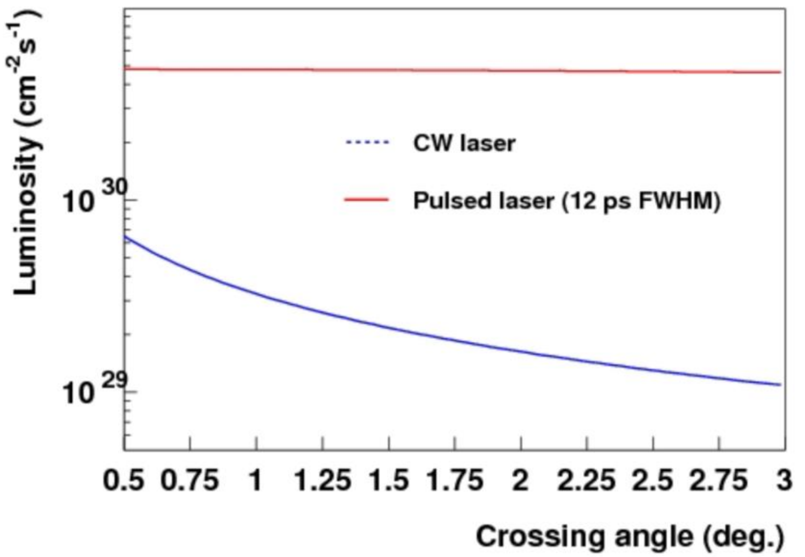
$$A_{\text{long}} = \frac{\sigma^{++} - \sigma^{-+}}{\sigma^{++} + \sigma^{-+}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} (1 - \rho(1+a)) \left[1 - \frac{1}{(1-\rho(1-a))^2} \right],$$

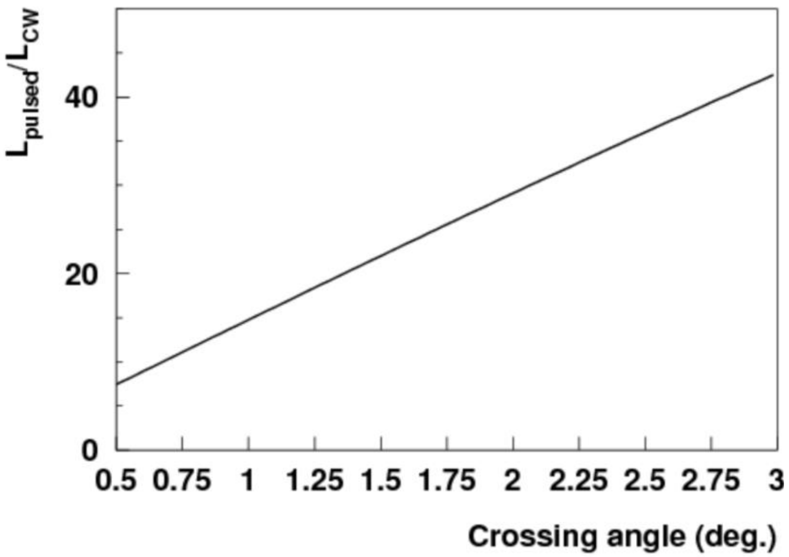
Atrans for 1, 5, 18 GeV (532 nm)



$$A_{\mathrm{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a) \frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))} \right].$$

DG proposal results

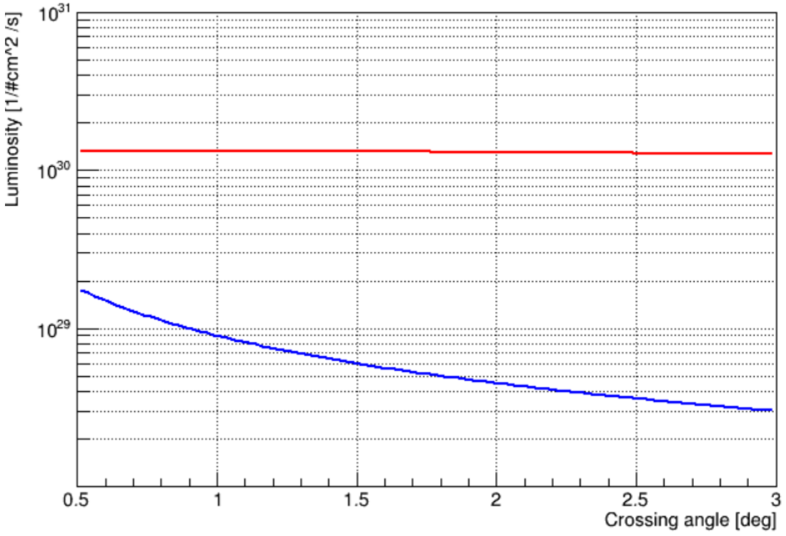


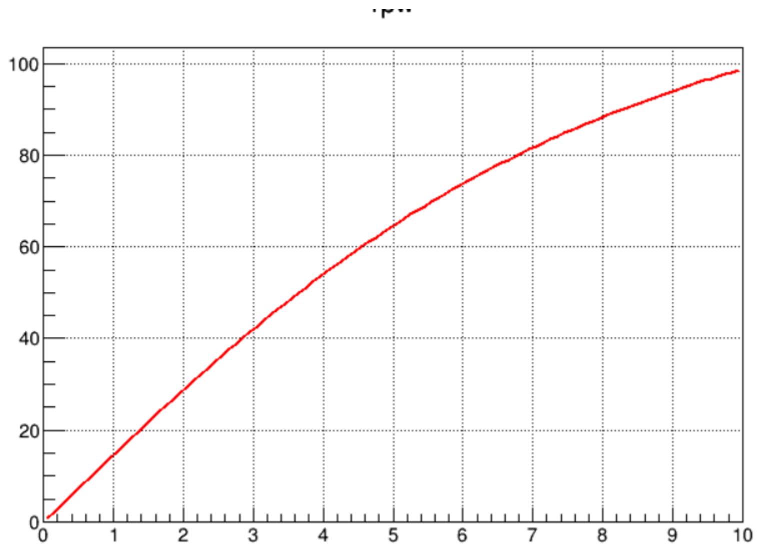



```
double eSigmaT = 100e-6; //m;
double gSigmaT = 100e-6; //m
double lPower = 1e3; //W
double nElectron = 1/1.6e-19 * 50e-6; //A/e-charge; #/s
double gSigmaL = 6e-12 * clight; //m -- 12ps FWHM
double eSigmaL = 0.5e-12 *clight; //5ps*c
double eFreq = 499e6; //499e6Hz CEBAF;
```

$$L_{CW} \approx \frac{(1+\cos(\alpha_c))}{\sqrt{2\pi}} \frac{I_e}{e} \frac{P_L \lambda}{hc^2} \frac{1}{\sqrt{\sigma_e^2+\sigma_\gamma^2}} \frac{1}{\sin(\alpha_c)}$$

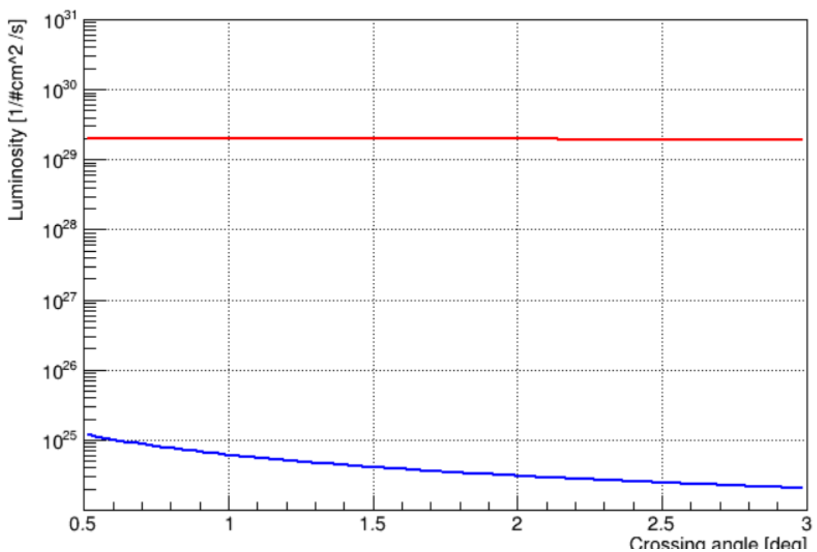
$$L_{pulsed} = \frac{(1+\cos(\alpha_c))}{2\pi f_{beam}} \frac{I_e}{e} \frac{P_L \lambda}{hc} \frac{1}{\sqrt{\sigma_e^2+\sigma_\gamma^2}} \frac{1}{\sin(\alpha_c)} \frac{1}{\sqrt{\sigma_{e,z}^2+\sigma_{\gamma,z}^2+\frac{(\sigma_e^2+\sigma_\gamma^2)}{\sin^2(\alpha_c/2)}}}$$

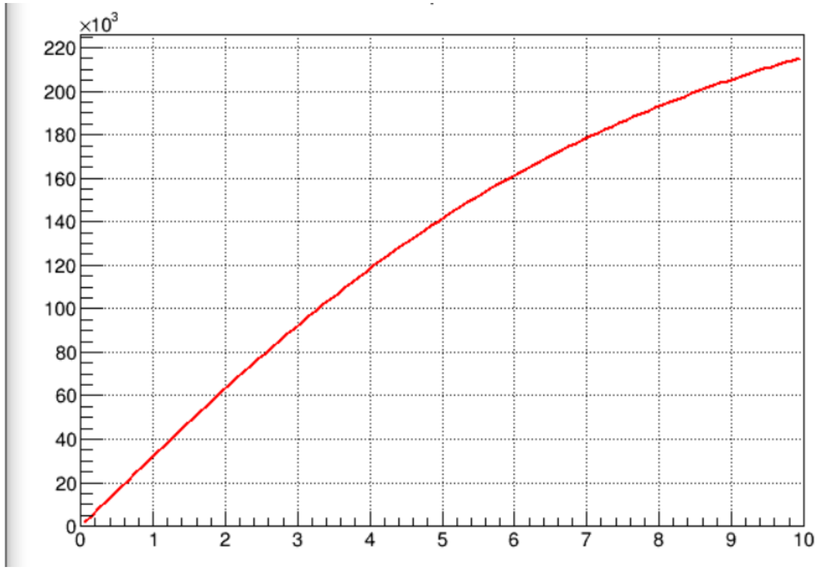




- There is a discrepancy in the my calculation
- It seems to come from "common" terms in luminosity calculations (the ratio seems ok)

Lumi calculations





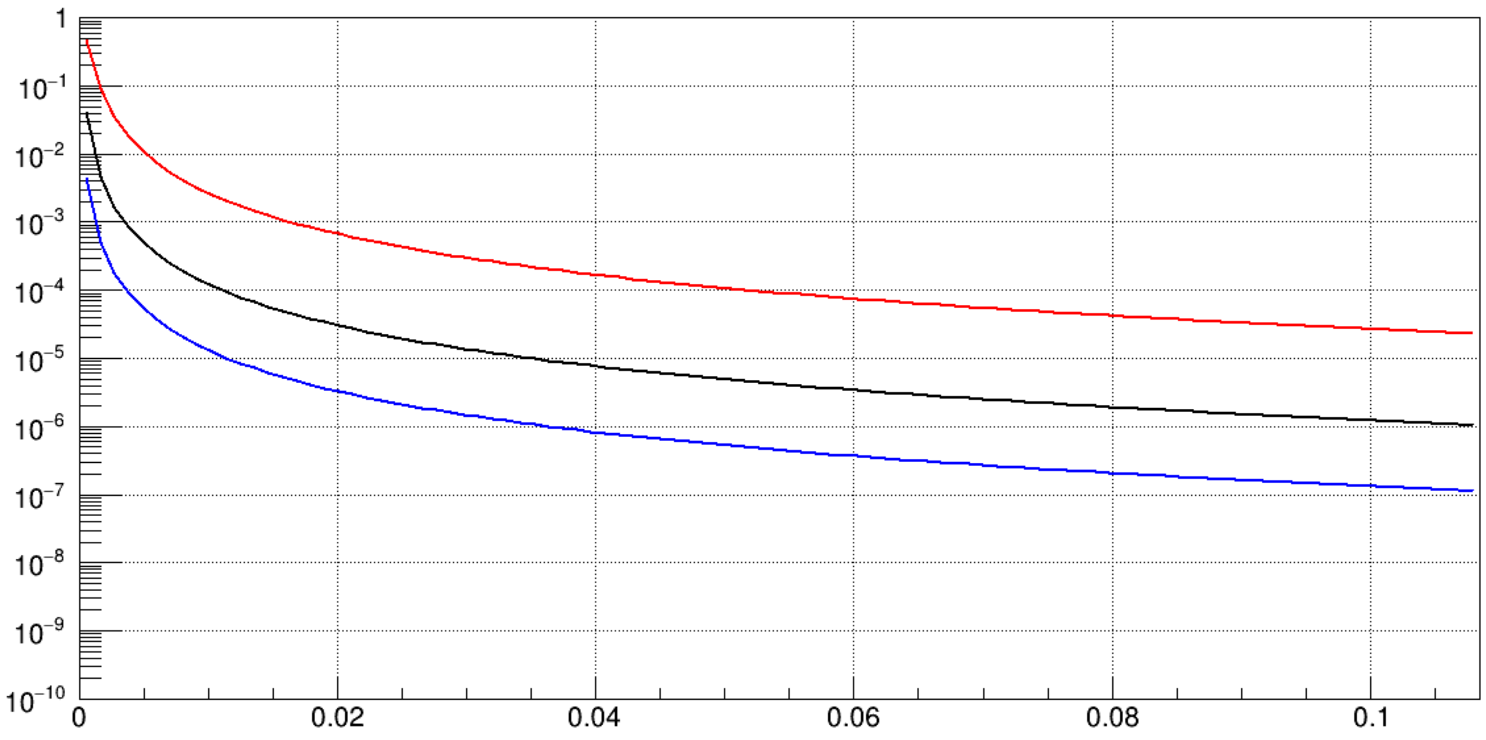

```
double eSigmaT = 400e-6; //m; eRHIC 40
double gSigmaT = 100e-6; //m
double gSigmaL = 12e-12 * clight; //m
double eSigmaL = 13e-12 *clight; //m ~
double lPower = 1e3; //W
double eFreq = 78e3; //98e6Hz (*6 buck
double nElectron = 1/1.6e-19 * 10e-9;
```

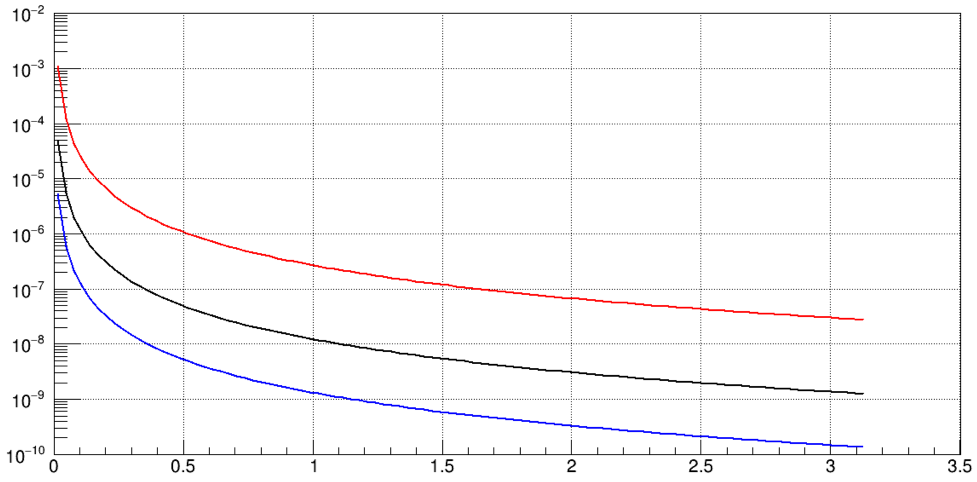
$$L_{pulsed} = \frac{(1+\cos(\alpha_c))}{2\pi f_{beam}} \frac{I_e}{e} \frac{P_L \lambda}{hc} \frac{1}{\sqrt{\sigma_e^2 + \sigma_\gamma^2}} \frac{1}{\sin(\alpha_c)} \frac{1}{\sqrt{\sigma_{e,z}^2 + \sigma_{\gamma,z}^2 + \frac{(\sigma_e^2 + \sigma_\gamma^2)}{\sin^2(\alpha_c/2)}}}$$

- Calculated the luminosity for the lowest charge (10nC) in the beam

beam energy [GeV]	e speed (c)	clight m/s	e speed m/s	length	time for one revol	frequency
1	0.9997444674	299792458	299715851.2	3834	0.0000127921162	78173.14847
5	0.9999488987	299792458	299777138.2	3834	0.0000127895009	78189.1336
18	0.9999858055	299792458	299788202.6	3834	0.0000127890289	78192.01945

Rho dependence on angle for 1, 5, 18 GeV (532 nm)

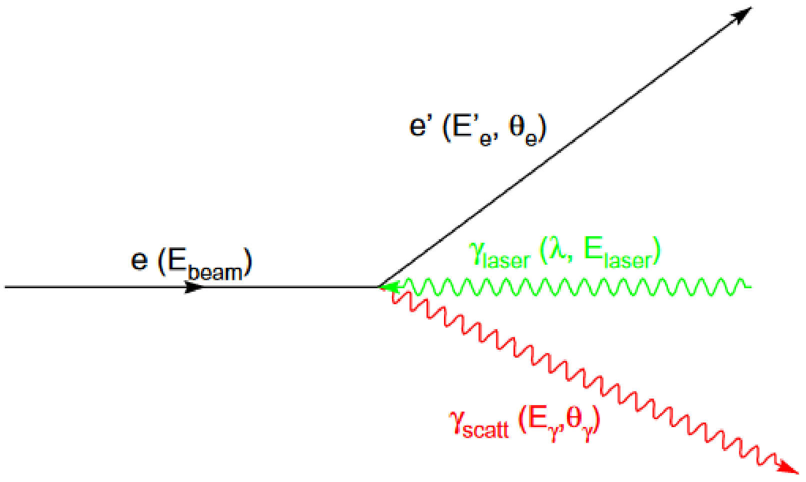




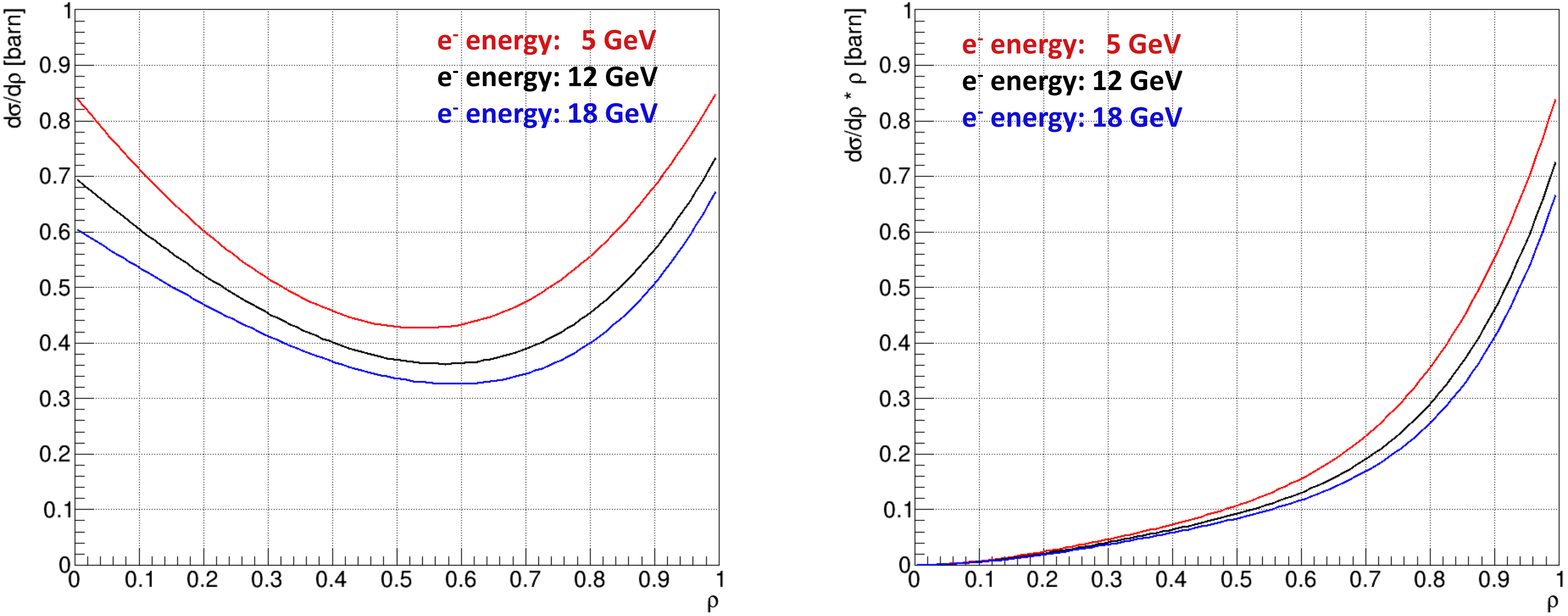
$$E_\gamma \approx E_{\text{laser}} \frac{4a\gamma^2}{1 + a\theta_\gamma^2\gamma^2},$$

$$E_\gamma^{\max} = 4aE_{\text{laser}}\gamma^2$$

$$\rho = E_\gamma / E_\gamma^{\max} \qquad a = \frac{1}{1 + 4\gamma E_{\text{laser}}/m_e}.$$

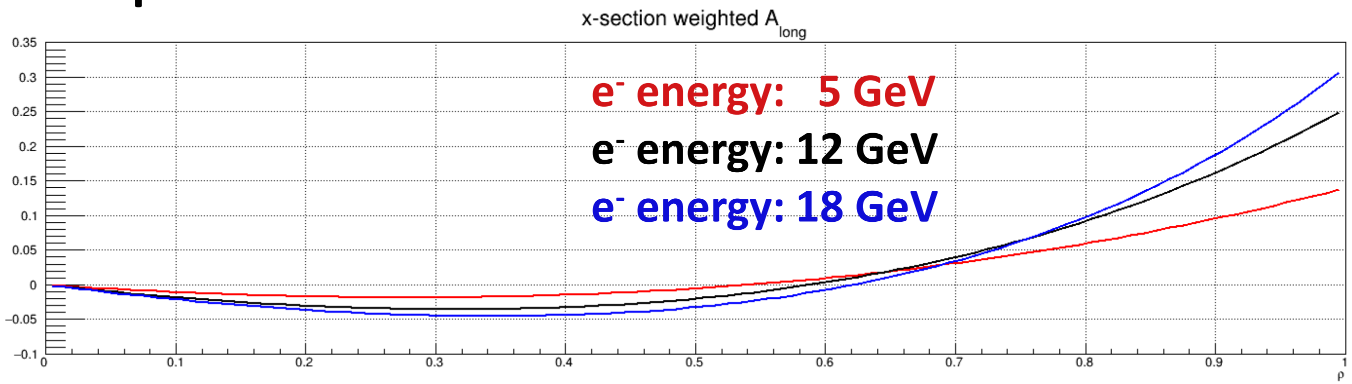


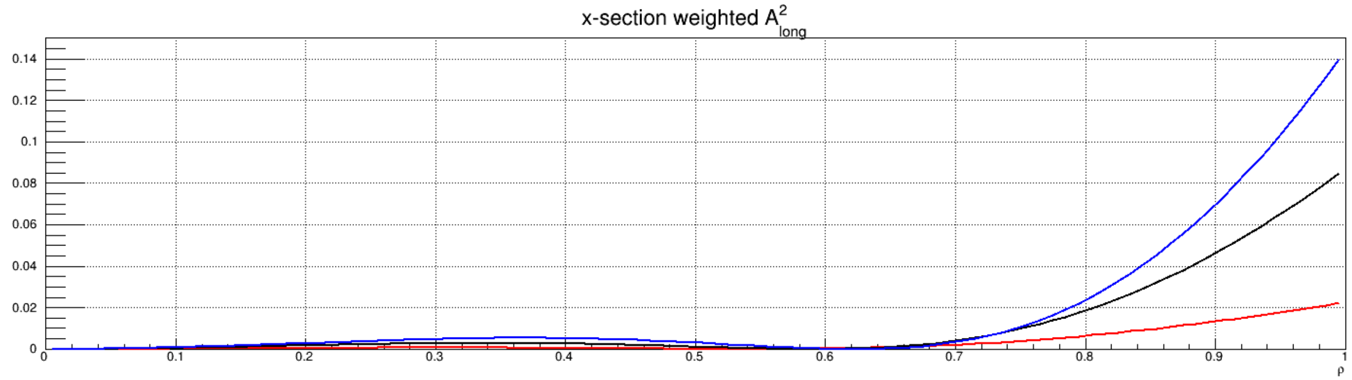
Unpolarized cross-section

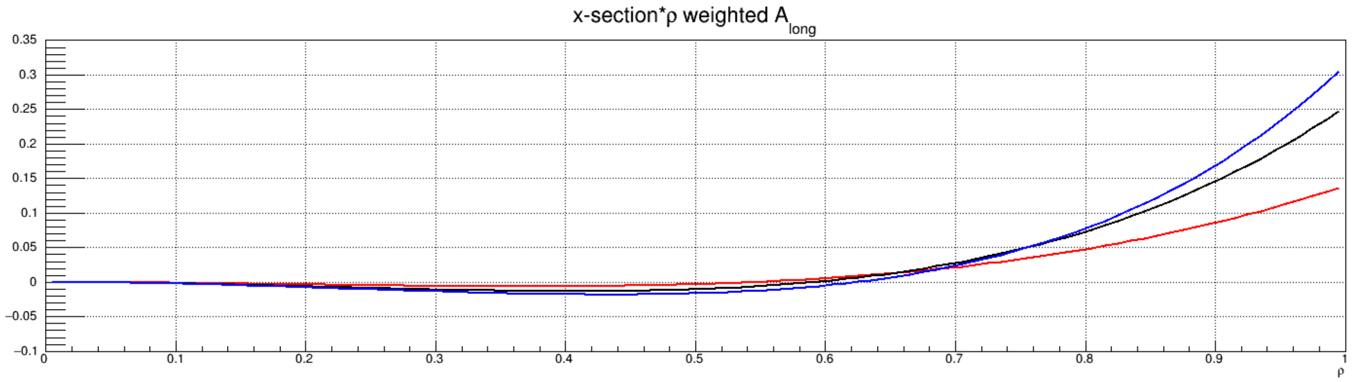


- The right plot is used for the <(E*A*sigma)^2>/<(E*sigma)^2>

Unpolarized cross-section







- Weighted asymmetries used for the statistics estimation

5 GeV

```
Xsec weighted AL: 0.0195011        <AL>: 0.0342786        <AL>^2: 0.00117502
Xsec weighted AL^2: 0.00344562     <AL^2>: 0.00605663
Xsec*E weighted AL: 0.0207725      <EAL>: 0.106342        <EAL>^2: 0.00220899
```

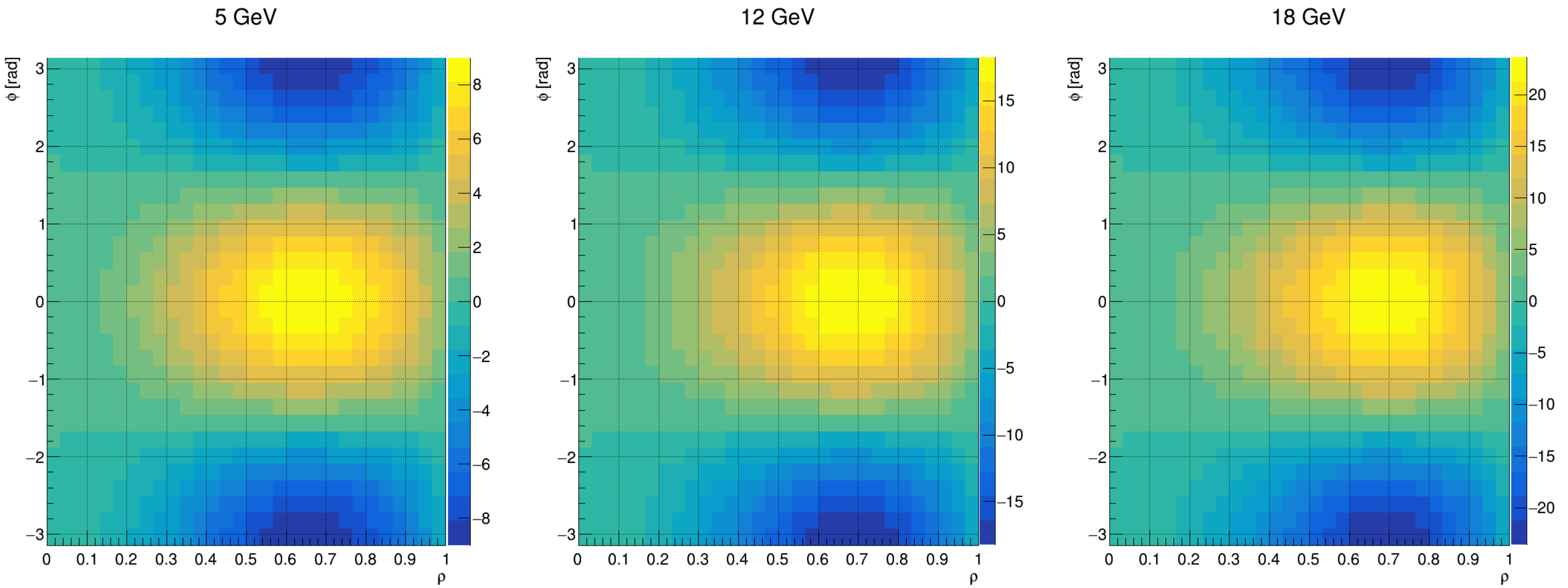
12 GeV

```
Xsec weighted AL: 0.0277547        <AL>: 0.0575526        <AL>^2: 0.0033123
Xsec weighted AL^2: 0.0117501      <AL^2>: 0.0243651
Xsec*E weighted AL: 0.0324336      <EAL>: 0.197934        <EAL>^2: 0.0064197
```

18 GeV

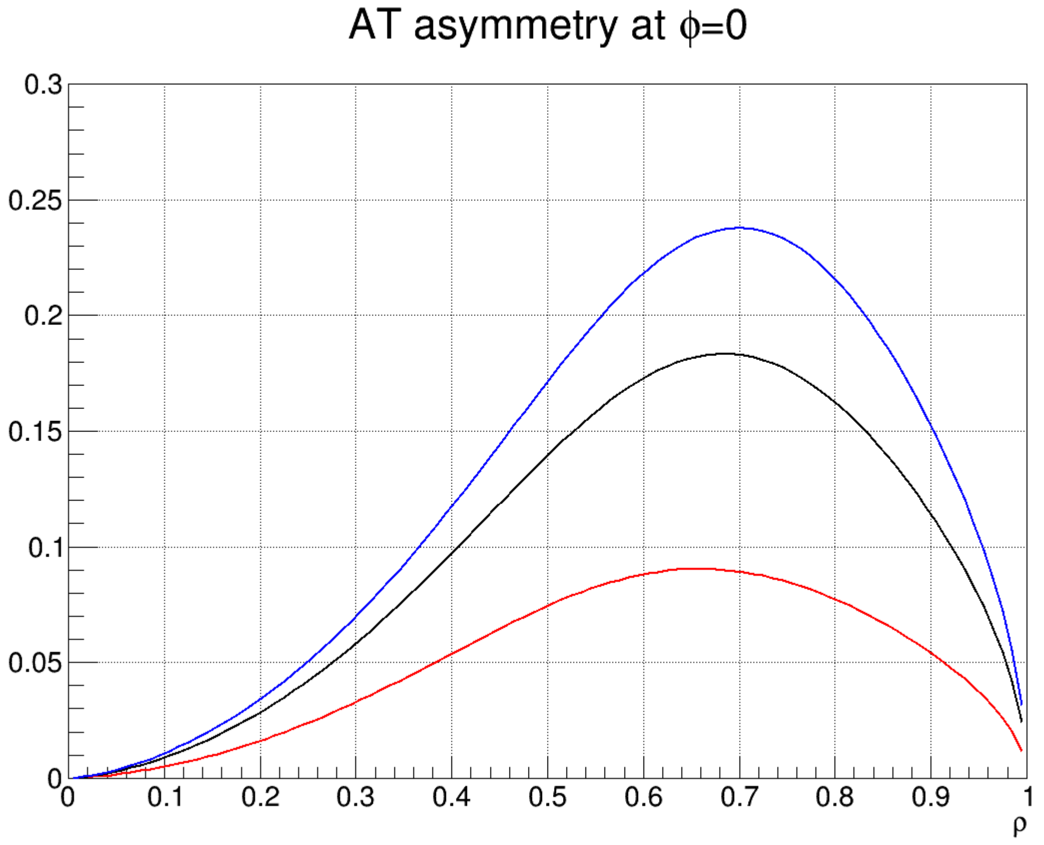
```
Xsec weighted AL: 0.0276725        <AL>: 0.0640455        <AL>^2: 0.00410183
Xsec weighted AL^2: 0.0178667      <AL^2>: 0.0413509
Xsec*E weighted AL: 0.0352449      <EAL>: 0.239876        <EAL>^2: 0.00845441
```

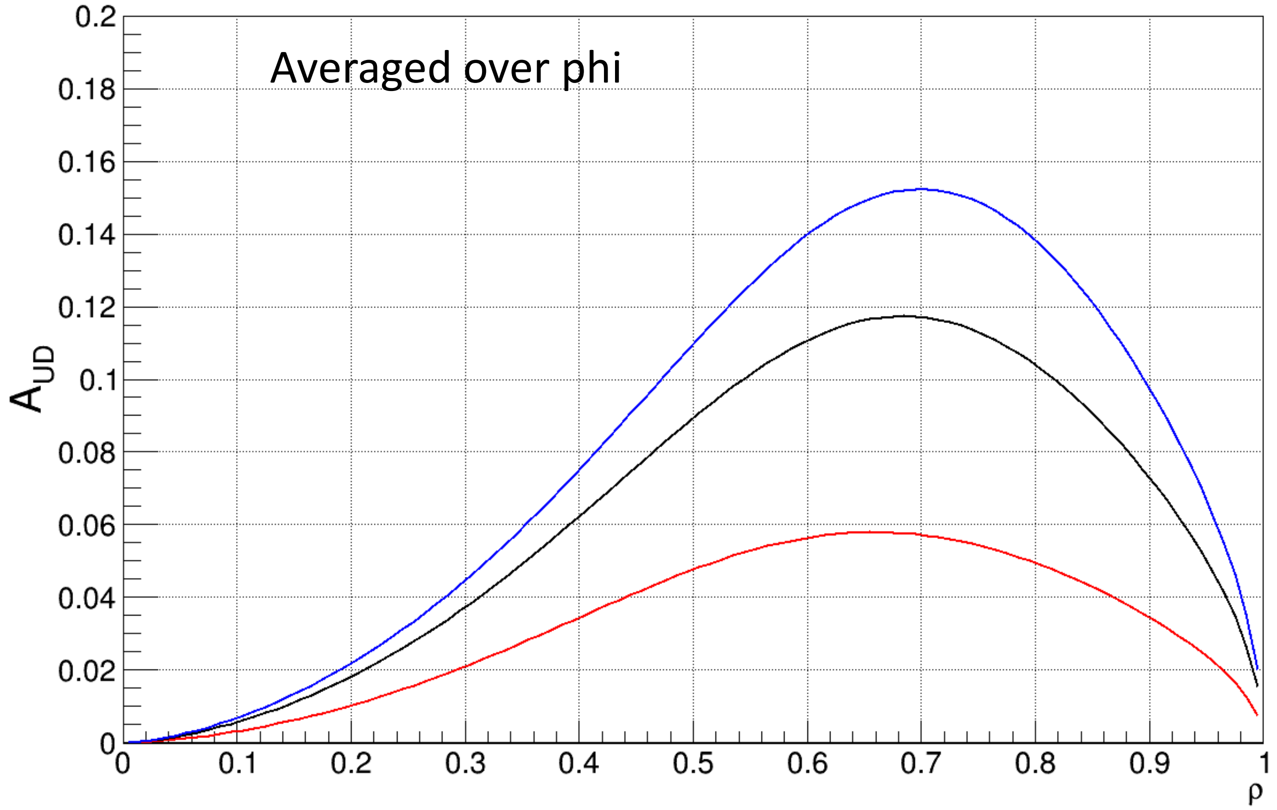
Atrans for 1, 5, 18 GeV (532 nm)



$$A_{\mathrm{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a) \frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))} \right].$$

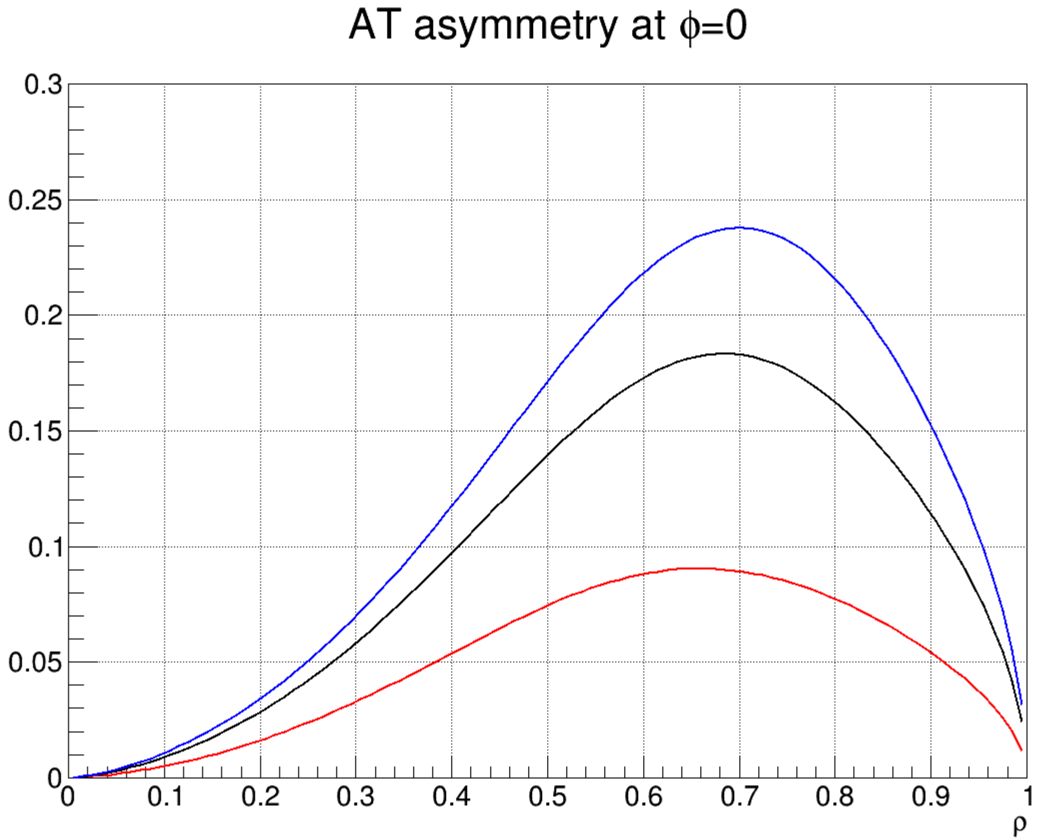
Atrans for 1, 5, 18 GeV (532 nm)

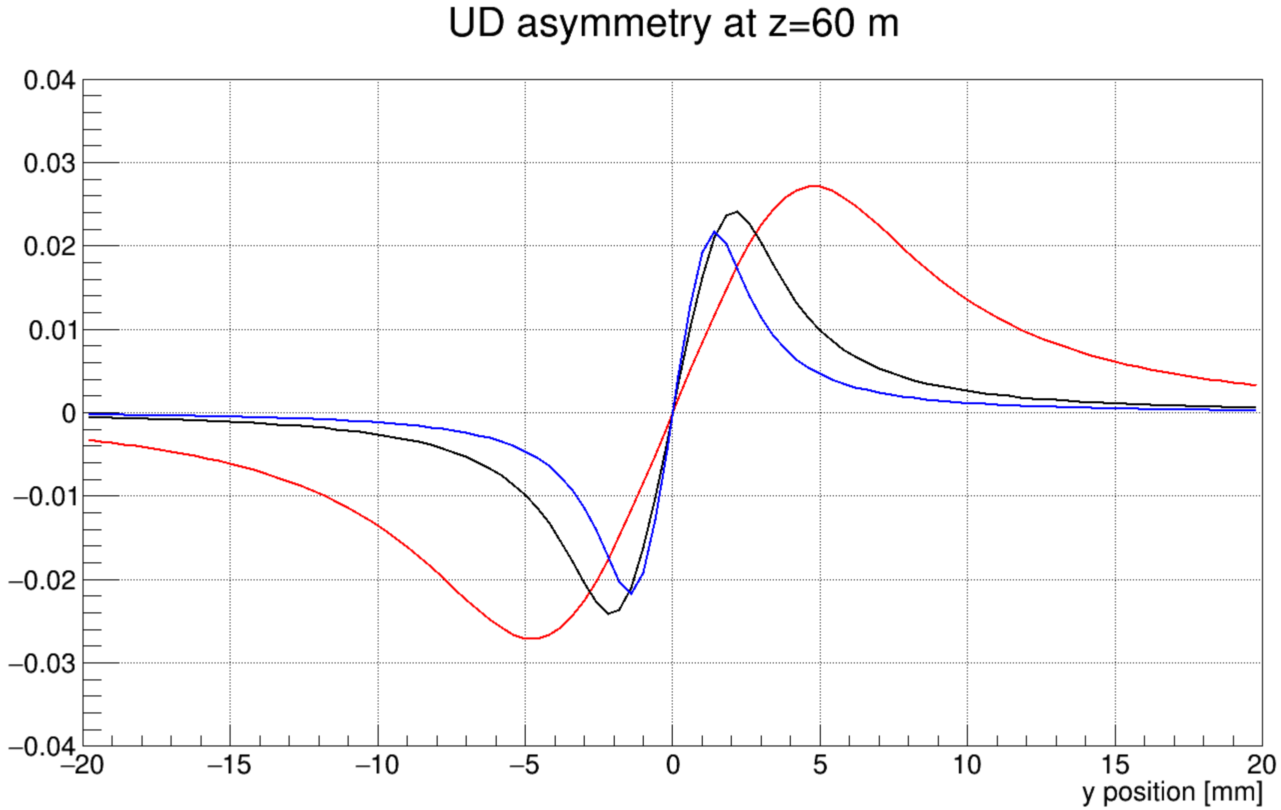




$$A_{\mathrm{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a) \frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))} \right].$$

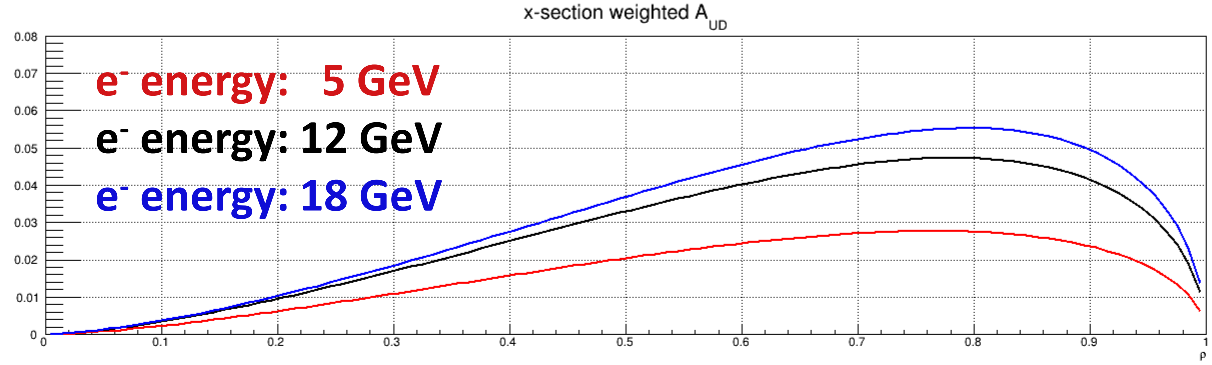
Atrans for 1, 5, 18 GeV (532 nm)

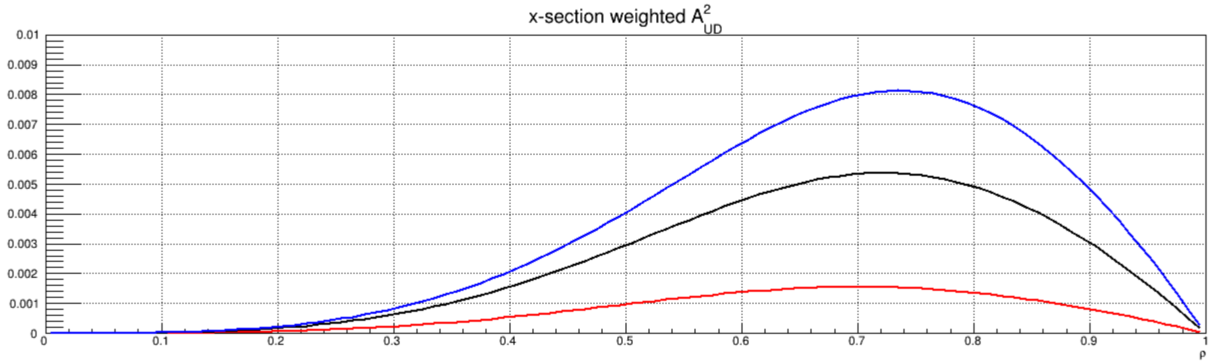


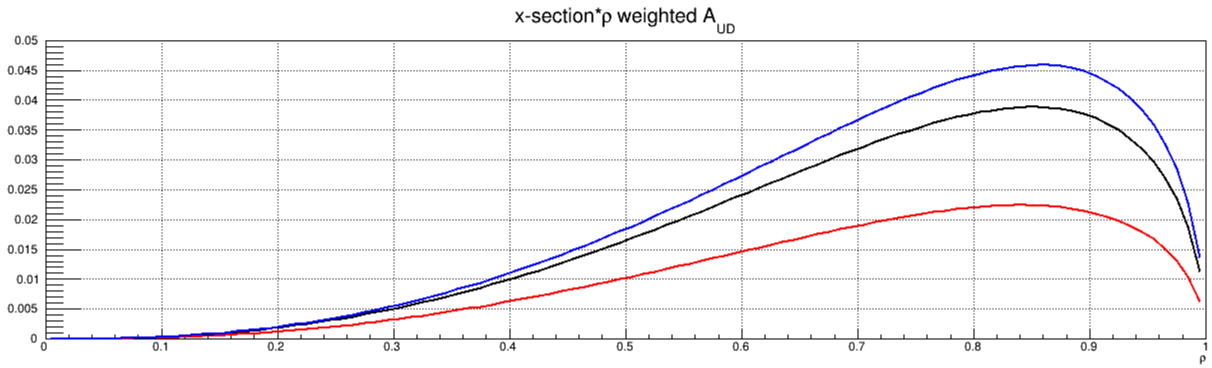


$$A_{\text{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a)\frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))}\right].$$

AUD asymmetry used for averages







5 GeV

```
Xsec weighted AUD: 0.0164237       <AUD>: 0.0288692        <AUD>^2: 0.000833428
Xsec weighted AUD^2: 0.000701338          <AUD^2>: 0.0012328
Xsec*E weighted AUD: 0.010392      <EAUD>: 0.0532007       <EAUD>^2: 0.000552863
```

12 GeV

```
Xsec weighted AUD: 0.0272893     <AUD>: 0.0565876        <AUD>^2: 0.00320216
Xsec weighted AUD^2: 0.00233609  <AUD^2>: 0.00484416
Xsec*E weighted AUD: 0.0175172   <EAUD>: 0.106903        <EAUD>^2: 0.00187264
```

18 GeV

```
Xsec weighted AUD: 0.0312334     <AUD>: 0.0722868        <AUD>^2: 0.00522538
Xsec weighted AUD^2: 0.00344939  <AUD^2>: 0.0079833
Xsec*E weighted AUD: 0.0202577   <EAUD>: 0.137874        <EAUD>^2: 0.00279302
```

Time calculations

$$t_{meth} = \frac{1}{\mathcal{L} \left(\frac{\Delta P_e}{P_e}\right)^2 P_e^2 P_\gamma^2} \frac{1}{A_{meth}^2} \frac{1}{\sigma_t},$$

$$< A_l >^2 < \frac{< E A_l >^2}{< E^2 >} < < A^2 >.$$

- For integral, energy weighted, differenatial

Measurement time for 1kW laser A_long

differential measurement		Laser: 532nm								
		Lpulsed (1kW)	2.00E+05	1/barn/s						
	beam energy [GeV]	Unpol Xsec[barn]	<A^2>	Pe	Pgamma	L (fbeam/xsection)	Power needed [kW]	1/t(1%)	t[s]	t[min]
	1	0.64255	3.01E-04	0.85	1	121660.8022	0.6083040111	1.70E-03	5.88E+02	9.79
	5	0.568901	6.06E-03	0.85	1	137438.9105	0.6871945523	3.42E-02	2.92E+01	0.49
	12	0.482249	2.44E-02	0.85	1	162139.1947	0.8106959733	1.38E-01	7.26E+00	0.12
	18	0.432076	4.14E-02	0.85	1	180968.208	0.9048410402	2.34E-01	4.28E+00	0.07
integrating measurement		Laser: 532nm								
	beam energy [GeV]	Unpol Xsec[barn]	<A>^2	Pe	Pgamma	L_pulsed [1/barn/s]	1/t(1%)	t_int	t[min]	
	1	0.64255	7.16E-05	0.85	1	200000	6.65E-04	1.50E+03	25.07	
	5	0.568901	1.18E-03	0.85	1	200000	9.66E-03	1.04E+02	1.73	
	12	0.482249	3.31E-03	0.85	1	200000	2.31E-02	4.33E+01	0.72	
	18	0.432076	4.10E-03	0.85	1	200000	2.56E-02	3.90E+01	0.65	
energy integrated										
		Unpol Xsec[barn]	<EA>^2/<E^2>	Pe	Pgamma	L_pulsed [1/barn/s]	1/t(1%)	t_int	t[min]	
	5	0.568901	2.21E-03	0.85	1	200000	1.82E-02	5.51E+01	0.92	
	12	0.482249	0.0064197	0.85	1	200000	0.04473566693	22.35352837	0.37	
	18	0.432076	0.00845441	0.85	1	200000	0.05278509362	18.94474238	0.32	

Measurement time for 1kW laser A_UD

differential measurement		Laser: 532nm								
		Lpulsed (1kW)	2.00E+05	1/barn/s						
	beam energy [GeV]	Unpol Xsec[barn]	<A^2>	Pe	Pgamma	L (fbeam/xsection)	Power needed [kW]	1/t(1%)	t[s]	t[min]
	5	0.568901	1.23E-03	0.85	1	137438.9105	0.6871945523	6.96E-03	1.44E+02	2.39
	12	0.482249	4.84E-03	0.85	1	162139.1947	0.8106959733	2.74E-02	3.65E+01	0.61
	18	0.432076	7.98E-03	0.85	1	180968.208	0.9048410402	4.51E-02	2.22E+01	0.37
integrating measurement		Laser: 532nm								
	beam energy [GeV]	Unpol Xsec[barn]	<A>^2	Pe	Pgamma	L_pulsed [1/barn/s]	1/t(1%)	t_int	t[min]	
	5	0.568901	8.33E-04	0.85	1	200000	6.85E-03	1.46E+02	2.43	
	12	0.482249	3.20E-03	0.85	1	200000	2.23E-02	4.48E+01	0.75	
	18	0.432076	5.23E-03	0.85	1	200000	3.26E-02	3.07E+01	0.51	
energy integrated										
		Unpol Xsec[barn]	<EA>^2/<E^2>	Pe	Pgamma	L_pulsed [1/barn/s]	1/t(1%)	t_int	t[min]	
	5	0.568901	5.53E-04	0.85	1	200000	4.54E-03	2.20E+02	3.67	
	12	0.482249	0.00187264	0.85	1	200000	0.01304948819	76.63135792	1.28	
	18	0.432076	0.00279302	0.85	1	200000	0.01743821534	57.34531776	0.96	

Time calculations-differential measurement (EA)

$$L_{pulsed} = \frac{(1+\cos(\alpha_c))}{2\pi f_{beam}} \frac{I_e}{e} \frac{P_L \lambda}{hc} \frac{1}{\sqrt{\sigma_e^2 + \sigma_\gamma^2}} \frac{1}{\sin(\alpha_c)} \frac{1}{\sqrt{\sigma_{e,z}^2 + \sigma_{\gamma,z}^2 + \frac{(\sigma_e^2 + \sigma_\gamma^2)}{\sin^2(\alpha_c/2)}}}$$

DG

$$L = \frac{f_b N_e N_\gamma}{2\pi \sigma_{x\gamma} \sigma_{y\gamma} \sqrt{1 + (0.5\theta \sigma_{z\gamma}/\sigma_{y\gamma})^2}}$$

R. Petti/Elke

$$N_{Compton}[s^{-1}] = L\sigma_{Compton}$$

$$N_{Compton}[bunch^{-1}] = L\sigma_{Compton}/f_b$$

- Not sure how they got to this Luminosity equation
- They assume the values to the right and assume 1 photon per crossing
  - Not sure why the frequency in this case is 9.4MHz

Parameter	value
f_b	9.4 MHz [3]
N_e	0.07×10^{11} [3]
σ_x	400 μm [10]
σ_y	400 μm [10]
σ_z	0.4 cm [3]
$\sigma_{Compton}$	400 mb

Time calculations-differential measurement

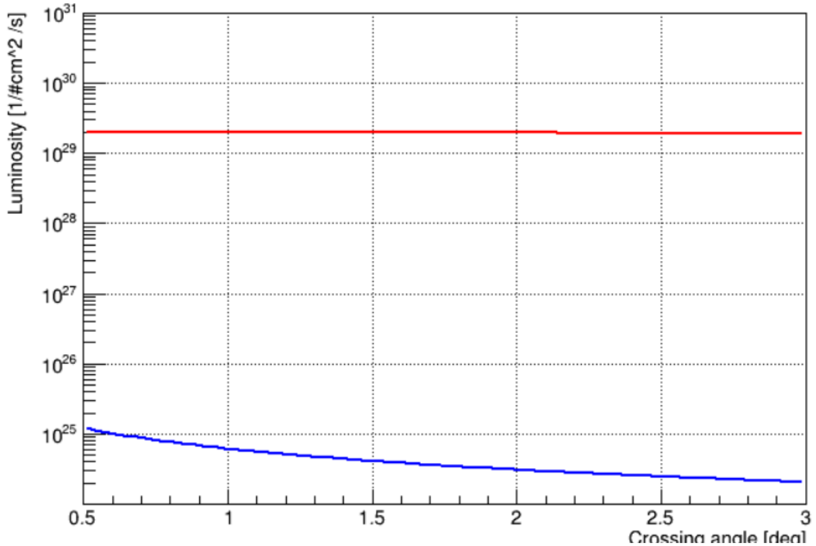
$$L_{pulsed} = \frac{(1+\cos(\alpha_c))}{2\pi f_{beam}} \frac{I_e}{e} \frac{P_L \lambda}{hc} \frac{1}{\sqrt{\sigma_e^2 + \sigma_\gamma^2}} \frac{1}{\sin(\alpha_c)} \frac{1}{\sqrt{\sigma_{e,z}^2 + \sigma_{\gamma,z}^2 + \frac{(\sigma_e^2 + \sigma_\gamma^2)}{\sin^2(\alpha_c/2)}}}$$

DG

```
double eSigmaT = 400e-6; //m; eRHIC 40
double gSigmaT = 100e-6; //m
double gSigmaL = 12e-12 * clight; //m
double eSigmaL = 13e-12 *clight; //m ~
double lPower = 1e3; //W
double eFreq = 78e3; //98e6Hz (*6 buck
double nElectron = 1/1.6e-19 * 10e-9;
```

beam energy [GeV]	Unpol Xsec[barn]	<A^2>	Pe	Pgamma	L (fbeam/xsection)	Power needed [kW]	1/t(1%)	t[s]	t[min]
1	0.64255	3.01E-04	0.85	1	121660.8022	0.6083040111	1.70E-03	5.88E+02	9.79
5	0.568901	6.06E-03	0.85	1	137438.9105	0.6871945523	3.42E-02	2.92E+01	0.49
18	0.432076	4.14E-02	0.85	1	180968.208	0.9048410402	2.34E-01	4.28E+00	0.07

- Xing angle at HERA was 3.3 deg (for the longitudinal Compton)
- I don't have updated values at the IR from eRHIC
  - The xy plane is not symmetric at all (flat almond shape)
- With the correct luminosity calculation it still seems that ~ 1kW (vs 12W) is needed for a less than 1min msmt
  - Backgrounds should be considered as well



Time calculations-integral measurement

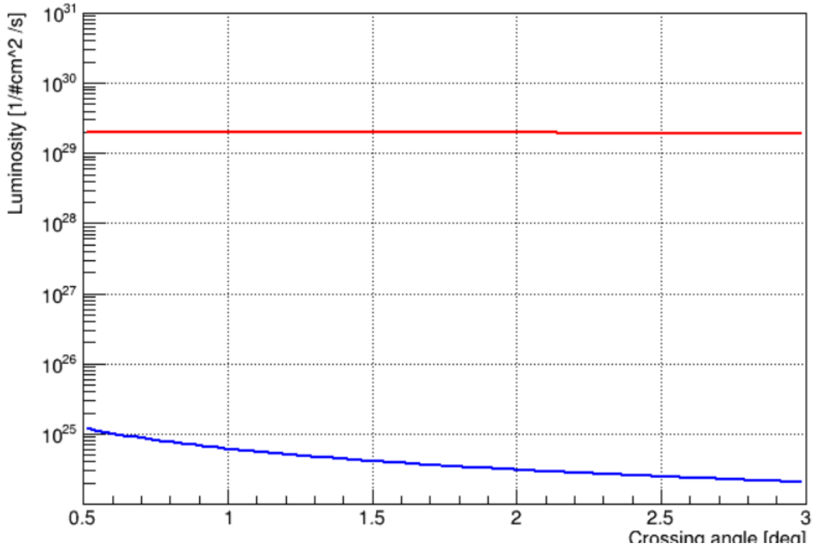
$$L_{pulsed} = \frac{(1+\cos(\alpha_c))}{2\pi f_{beam}} \frac{I_e}{e} \frac{P_L \lambda}{hc} \frac{1}{\sqrt{\sigma_e^2 + \sigma_\gamma^2}} \frac{1}{\sin(\alpha_c)} \frac{1}{\sqrt{\sigma_{e,z}^2 + \sigma_{\gamma,z}^2 + \frac{(\sigma_e^2 + \sigma_\gamma^2)}{\sin^2(\alpha_c/2)}}}$$

DG

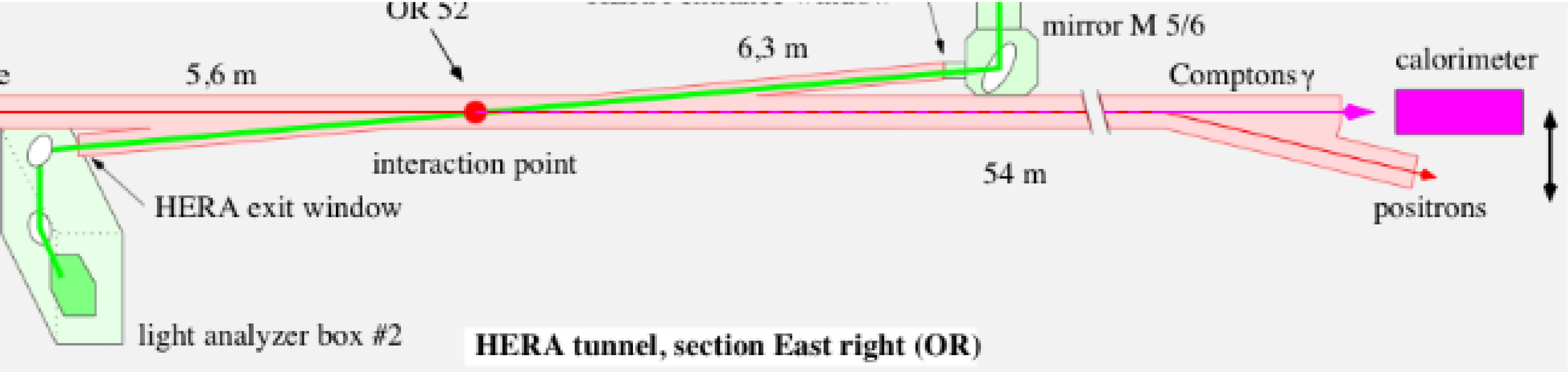
```
double eSigmaT = 400e-6; //m; eRHIC 40
double gSigmaT = 100e-6; //m
double gSigmaL = 12e-12 * clight; //m
double eSigmaL = 13e-12 *clight; //m ~
double lPower = 1e3; //W
double eFreq = 78e3; //98e6Hz (*6 buck
double nElectron = 1/1.6e-19 * 10e-9;
```

beam energy [GeV]	Unpol Xsec[barn]	<A>^2	Pe	Pgamma	L_pulsed [1/bam/s]	1/t(1%)	t_int	t[min]
1	0.64255	7.16E-05	0.85	1	200000	6.65E-04	1.50E+03	25.07
5	0.568901	1.18E-03	0.85	1	200000	9.66E-03	1.04E+02	1.73
18	0.432076	4.10E-03	0.85	1	200000	2.56E-02	3.90E+01	0.65

- Xing angle at HERA was 3.3 deg (for the longitudinal Compton)
- The asymmetry weighting shows up here, but it's not that big of a deal (factor 3 for 5 GeV and factor 9 for 18 GeV)



HERA LPOL



- Crossing angle should be about 0.4758 rad (27 deg?!)
- Single photon mode: ngamma= 0.001 per crossing; s/b=0.2; 1%msmt at 2.5h
- Multiphoton mode: ngamma=1000; pulsed laser 100Hz (HERA 10MHz); 1% 1min

HERA LPOL

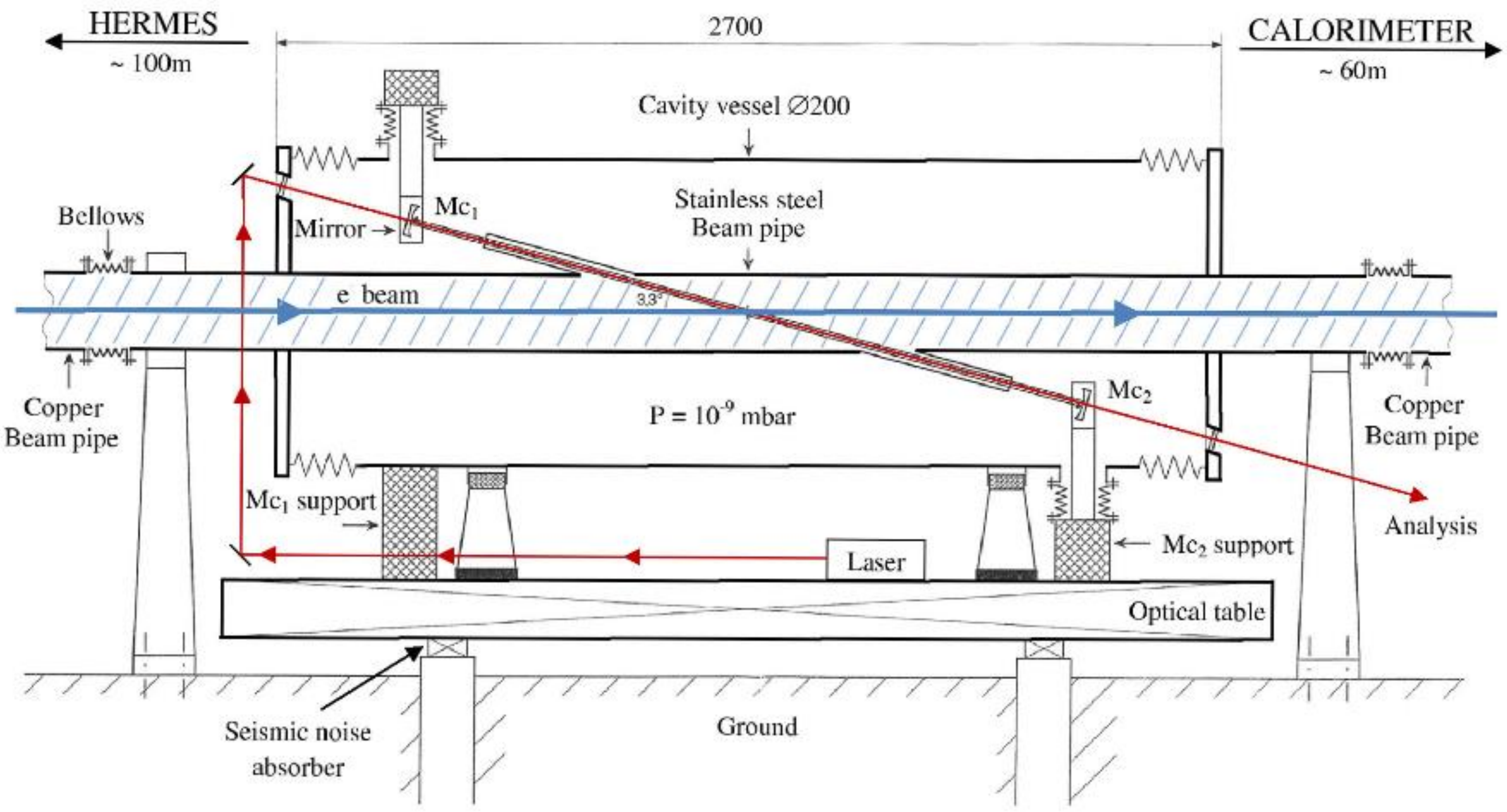
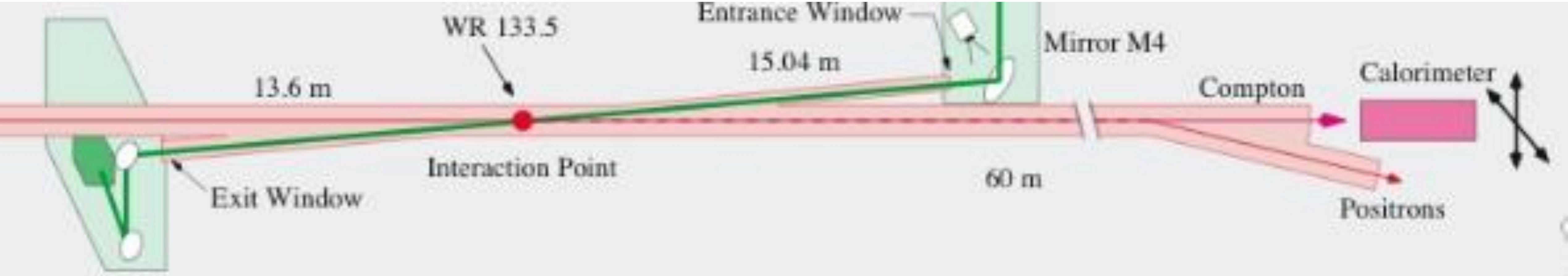


Figure 1. Scheme of the cavity surrounding the electron beam pipe with the laser and main mirrors.

- Crossing angle 3.3 deg (58mrad)
- Single photon mode: ngamma= 0.001 per crossing; s/b=0.2; 1%msmt at 2.5h
- Multiphoton mode: ngamma=1000; pulsed laser 100Hz (HERA 10MHz); 1% 1min

HERA TPOL



- Crossing angle should be about 0.4411 rad (25 deg?!)

eRHIC parameters (max luminosity)

Table 1: Maximum Luminosity Parameters

Parameter	***hadron***	***electron***
Center-of-Mass Energy [GeV]	104.9	
Energy [GeV]	275	10
Number of Bunches	1320	
Particles per Bunch [10^{10}]	6.0	15.1
Beam Current [A]	1.0	2.5
Horizontal Emittance [nm]	9.2	20.0
Vertical Emittance [nm]	1.3	1.0
Hor. β-function at IP β_x^* [cm]	90	42
Vert. β-function at IPβ_y^* [cm]	4.0	5.0
Hor./Vert. Fractional Betatron Tunes	0.3/0.31	0.08/0.06
Horizontal Divergence at IP [mrad]	0.101	0.219
Vertical Divergence at IP [mrad]	0.179	0.143
Horizontal Beam-Beam Parameter ξ_x	0.013	0.064
Vertical Beam-Beam Parameter ξ_y	0.007	0.1
IBS Growth Time longitudinal/horizontal [hours]	2.2/2.1	-
Synchrotron Radiation Power [MW]	-	9.18
Bunch Length [cm]	5	1.9
Hourglass and Crab Reduction Factor	0.87	
Luminosity [10^{34}cm-2sec-1]	1.05	

- 18 GeV bunches replaced every 6 min
- 10 nC ~ 6e10 e- per bunch
- Half of the bunches collide at each IR
- Energy in the Rapid cycling synchrotron is from 5 GeV to 18 GeV
    - Luminosity will be below 1e33 for E<5GeV
- 22mrad crossing angle

Compton Polarimeter summary

Table 7. Compton polarimeters including nominal operating energies and performance. Not all Compton polarimeters are included in the table — an emphasis has been placed on those used to provide absolute beam polarization measurements.

Polarimeter	Beam energy	Laser wavelength and technology	Detection and method	Sys. uncertainty (dP/P)	References
CERN LEP	46 GeV	532 nm (pulsed)	γ/integrating	5%	99, 100
HERA LPOL	27.5 GeV	532 nm (pulsed)	γ/integrating	1.6%	85
HERA TPOL	27.5 GeV	514 nm (CW)	γ/counting	2.9%	92, 101
MIT-Bates	0.3–1 GeV	532 nm	γ/counting	6%	95, 96
NIKHEF	<1 GeV	514 nm	γ/counting	4.5% @ 440 MeV	94
Mainz A4	0.85,1.5 GeV	514 nm intra-cavity Ar–ion	(γ,e)/counting	N/A	98
JLab Hall A	1–6 GeV	1064 nm, FP cavity	γ/counting	3% (2002)	81
			e/counting	1% (2006)	102
			γ/integrating	1% (2009)	103
	1.1 GeV	532 nm, FP cavity	γ/integrating	1.1% (2010)	104, 9
JLab Hall C	1.1 GeV	532 nm, FP cavity	e/counting	0.6%	82
			γ/integrating	3%	105
SLD at SLAC	45.6 GeV	532 nm (pulsed)	e/multiphoton	0.5%	86, 106

Laser wavelength - power