WP3 conclusion

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Introduction: Physics requirements

- transverse polarimeter for RDP of pilots:
  - ~1000 scattered particles/crossing (precision~0.5%/s)
- Longitudinal polarimeter (rate counting) for precession of pilots:
  - ~1000 scattered particles/crossing (precision~0.5%/s)
- transverse polarimeter for colliding bunches
  - Accuracy ~<1e-3 for (~vanishing) transverse polarisation (→~<1e-5 longitudinal for physics at IP)
- Ability to measure beam energy
  - from the scattered electron transverse distribution

Laser system

- Mostly an operational matter
- Versatile modern technology (Yb modelock laser)
- Use same laser oscillator (synced on RF) for all scenarii (but different amplifiers operated in parallel)
- Laser parameter table to be updated for the various foreseen locations and operational scenarii
- Control of laser polarisation and measuring it precisely are essential
  - Typically 10-3 achieved (SLC, HERA LPOL, JLAB). Achieving 10-5 accuracy on polarisation measurement is not impossible but required R&D and very careful design (QWP or photo-elastic modulator) and material choice.

Some possible laser systems

Nikolai's baseline

NB: e-beam size now about 500um
Laser-beam size ~1mm

Laser param.	1 pilot	1 pilot v2	All colliding bunches (at Z)
Repetition rate	3 kHz	3 kHz	50 MHz
Pulse energy	1 mJ	1 mJ	100 nJ
Pulse duration	5 ns	5 ps (**)	5 ps (**)
Average power	3 W	3 W (***)	5 W (***)
Scattering rate	$1x10^5$/s (*)	$2x10^5$/s (****)	$6x10^6$/s (****)
Scattering rate per bunch	$1x10^5$/s (*)	$2x10^5$/s	$4x10^2$/s

Same oscillator may be used but two different amplification schemes
Scheme for colliding can be adapted to a burst mode operation (166 successive bunches with 100 times more laser energy/bunch)

(*) Large piwinski contribution, nearly scales as crossing angle, very dependent on laser beam size (was $2x10^6$/s in ref. paper)
(**) Short pulse duration → broader laser spectrum, energy measurement from threshold more difficult
(***) Can be increased to typically ~100W (nowadays) but requires operational validation, management of thermal effects…
(****) not limited by Piwinski contribution → significantly increases when decreasing laser beam size

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A factor 10 too small wrt to specs of slide 2.
→ Reduce laser beam size
→ Amplitude of transverse excursions of beam ?

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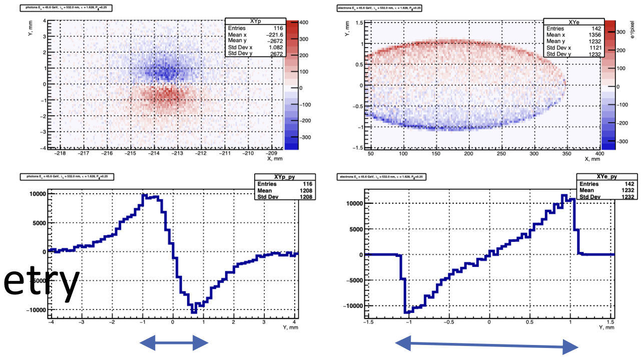
Detectors

- Simulations must be pursued to investigate on ideal/perfect detector what is acceptable pixel size
- Check concept is OK for the various operational scenarii and statistical precision is met
- Iterate with reasonable integration assumptions
- Background ←→ integration ?
- Decide on detector and realize detailed simulations to include resolution effects
  - ~<0.3mm spatial resolution needed
- Software development profit from EIC work?

Transverse asymetry



2mm

Integration

- Laser would need a dedicated laser room close to interaction chamber , laser beam transport → follow-up with integration
    - EIC will test high power optical fiber transmission
- Interaction chamber studied for SuperKEKb (2/4 degrees angle) apparently not an issue for impedance.
    - EIC team will actually perform impedance studies soon.
- Current concept ~2mrad precisely known spectrometer magnet, 100m drift behind
    - Who could provide design ?
- Two locations upstream IP or RF proposed (M. Hofer)
    - Upstream IP difficult → less space, upstream RF looks better

Next steps

- Draft of functional specs to be circulated
- simulations for various scenarii, locations and operating energies (Z, WW)
- Integration concept (room, laser transport) to be discussed
  - Main cost driver
- Polarisation control need demonstration at ~<1e-3 precision AND accuracy → need (longterm) R&D (€€,manpower)
- Detector concept must be clarified still and simulated (manpower)
- Keep contact with EIC polarimetry group in the future

Supplementary material

Scattered photon rate

Laser-beam single pulse energy

Compton cross-section

Electron bunch charge

Geometrical factor

Photon rate $n = \sigma_C \frac{\mathcal{E}}{E_\lambda} \frac{Q}{q} \frac{\mathcal{F}}{4\pi\sigma_y\sigma_x}$

- $\mathcal{F}^{-1} = \sqrt{1 + \left(\frac{\sigma_z}{\sigma_x}\tan\frac{\theta_0}{2}\right)^2}$
- $\theta_0 \sim 2mrad$

Transverse beam sizes:

- $\sigma_{x,y,z} = \sqrt{\sigma^2_{x,y,z,laser} + \sigma^2_{x,y,z,e-}}$
- $\sigma_{x,laser} = \sigma_{y,laser}$=1mm

Laser photon energy
(2.4eV for 0.5µm wavelengths)

Upstream RF location, From K. Oide

@Z		pilot	colliding
Collision		N	Y
Bunches/beam		~ 100	10000
Particles/bunch	10^{10}	~ 1	24.3
Energy spread	10^{-4}	3.8	13.2
Bunch length	mm	4.38	15.4
ε_x	nm	1.4	1.4
$\varepsilon_y/\varepsilon_x$	%	$\lesssim 0.1$	0.2
σ_x@laser / polm	mm	0.523 / 1.039	0.525 / 1.039
σ_y@laser / polm	mm	($\lesssim 0.007$) / 0.027	0.012 / 0.027

Compton polarimeter layout

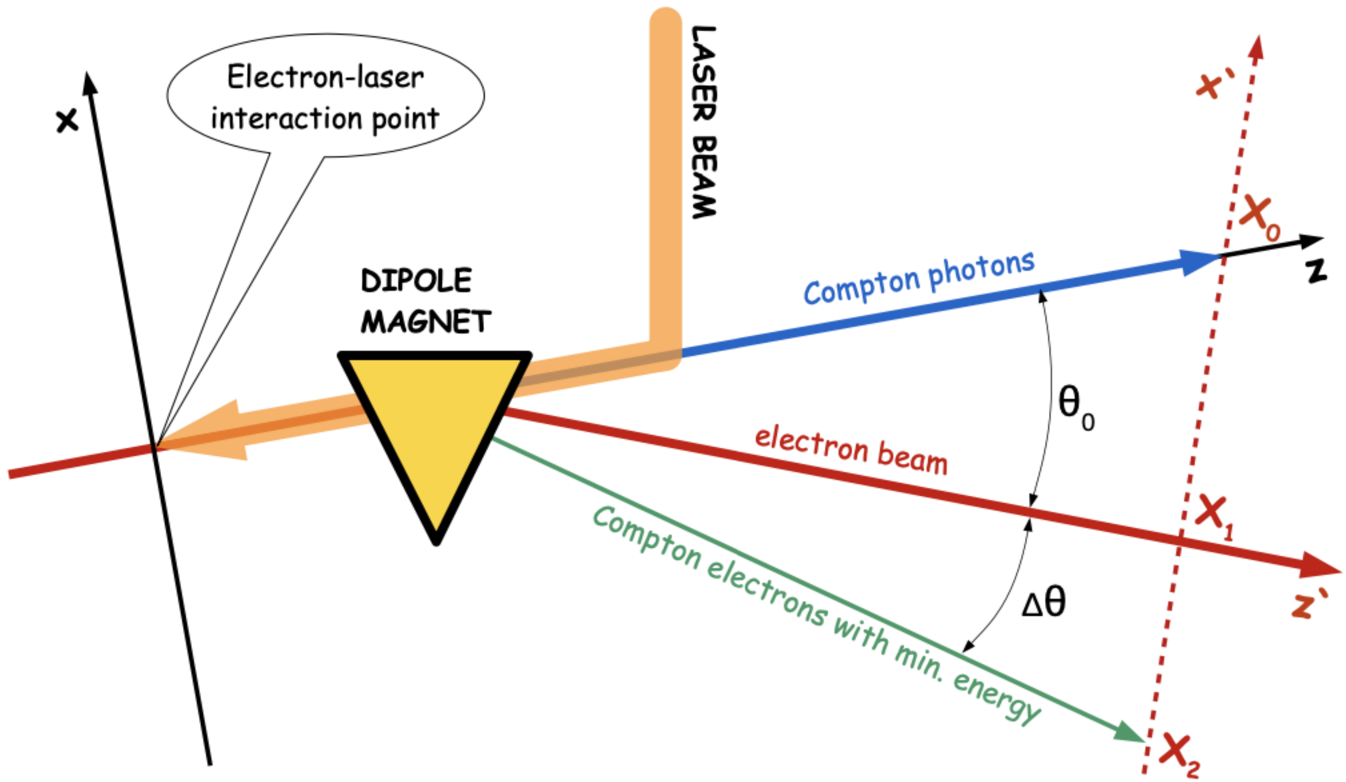


Figure 25. Regular layout of ICS experiments realization.

Redundancy: measure both electrons and photons

Berestskii & Lfshitz QED textbook

Compton cross-section

$$x = \frac{2E_0\omega_0}{m^2}(1+\cos\alpha)$$

$$x = \frac{2E_0\omega_0}{m^2}(1+\cos\alpha) \qquad y = \frac{E_\gamma}{E_0}$$

The Compton cross-section averaged over scattered particles spins:

Differential cross-section

Transverse laser polarisation: nuisance parameter to minimize and keep under control

Transverse electron beam polarisation: intervenes as an asymmetry in the transverse plane

$$\frac{d\sigma}{dy d\varphi_{obs}}(x,y) = \frac{d\sigma_0}{dy}(x,y) + \frac{d\sigma_\perp}{dy}(x,y)\cos\big(2(\varphi_{obs}-\varphi_{las})\big)\mathcal{P}_\perp^{las} + \frac{d\sigma_\parallel}{dy}(x,y)\mathcal{P}_C^{las}\left(P_T f_T(x,y)\cos(\varphi_{obs}-\varphi_{elec}) + P_L f_L(x,y)\right)$$

Electron beam polarization independent | *Electron beam polarization dependent*

⚠ But small opening angle of scattered particles:

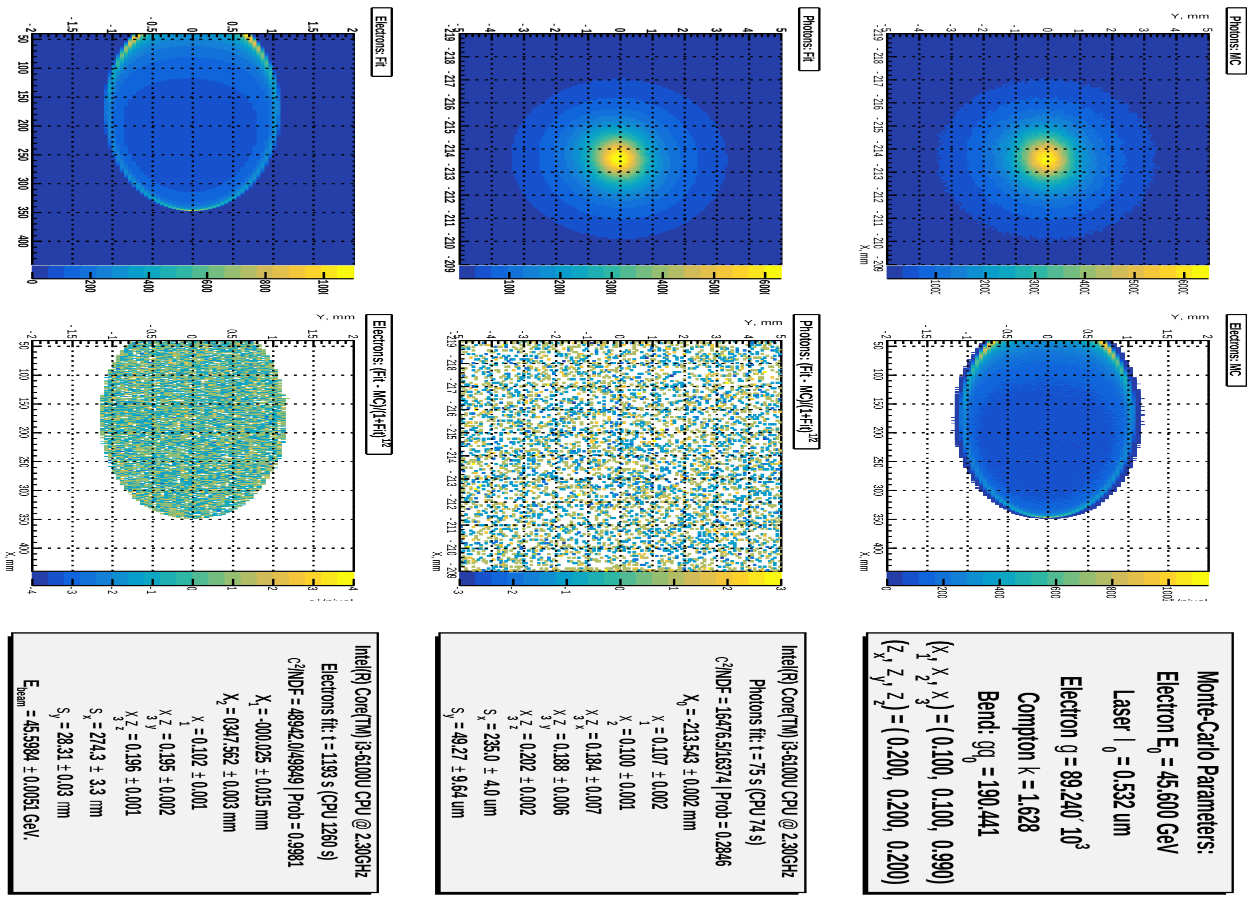
- Electrons → spectrometer
- Photons → difficult to measure asymmetric distribution of a narrow spot → long lever arm needed

in a few seconds for pilots

Transverse distributions

Nickolai's presentation

Based on measurement of scattered particles transverse distributions (p… detectors)



All components extracted with ~0.001 precision in few seconds

Beam energy may be extracted too! → redundancy

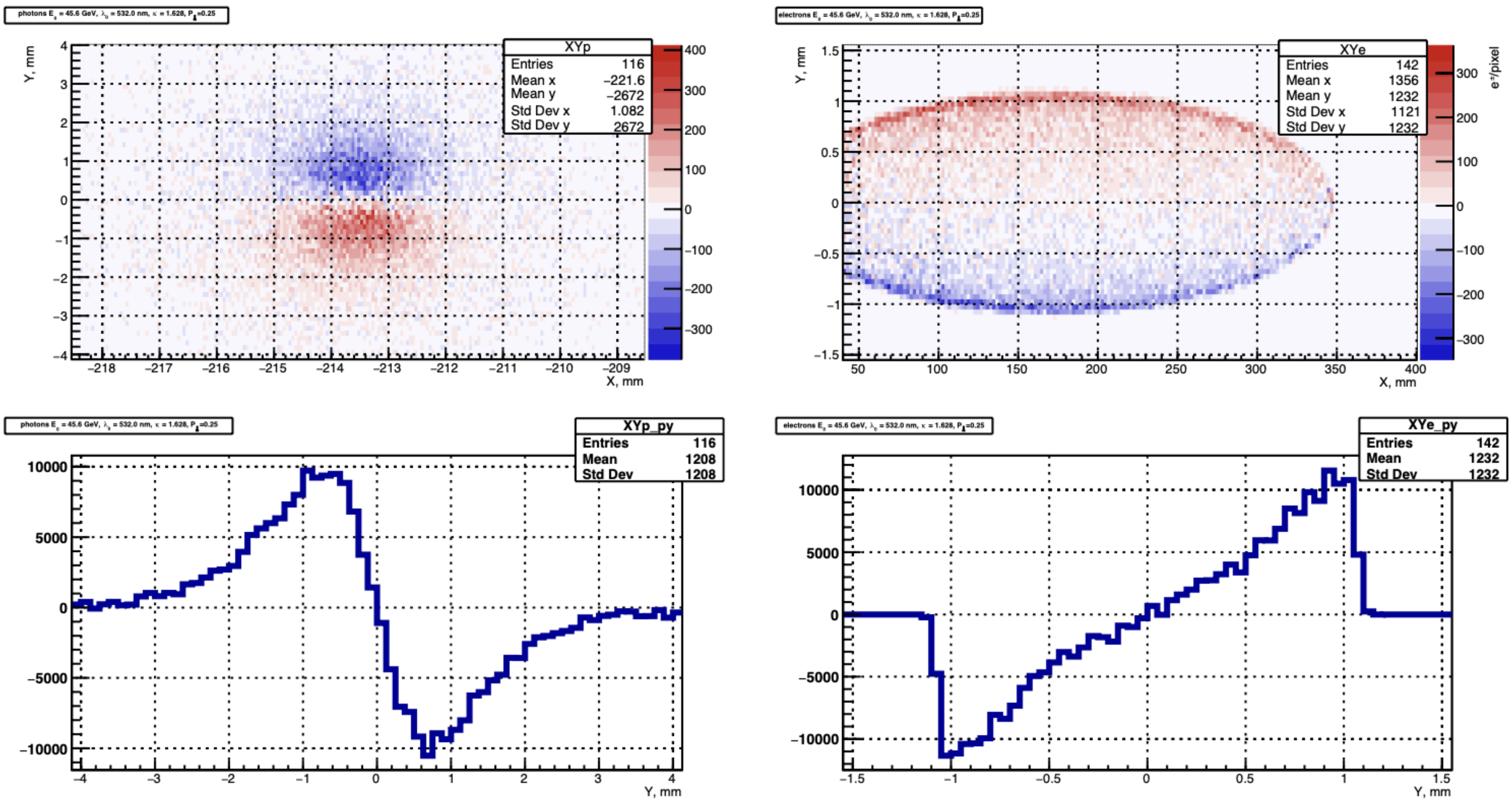
Realistic detector specifications to be drawn

Open questions: detector spatial resolution, longitudinal sampling, rates, combined fits, laser polarization flips,…

Blondel et al., arXiv:1909.12245

Laser helicity asymmetries

Nickolai's presentation



Reproductible and well known laser helicity flip is required

Blondel et al., arXiv:1909.12245