Laser diagnostics at LUXE

- **LUXE is going to be the first experiment try to measure the nonlinear QED features with unprecedented accuracy and ample statistics**

- **Key players in boiling down the vacuum are:**

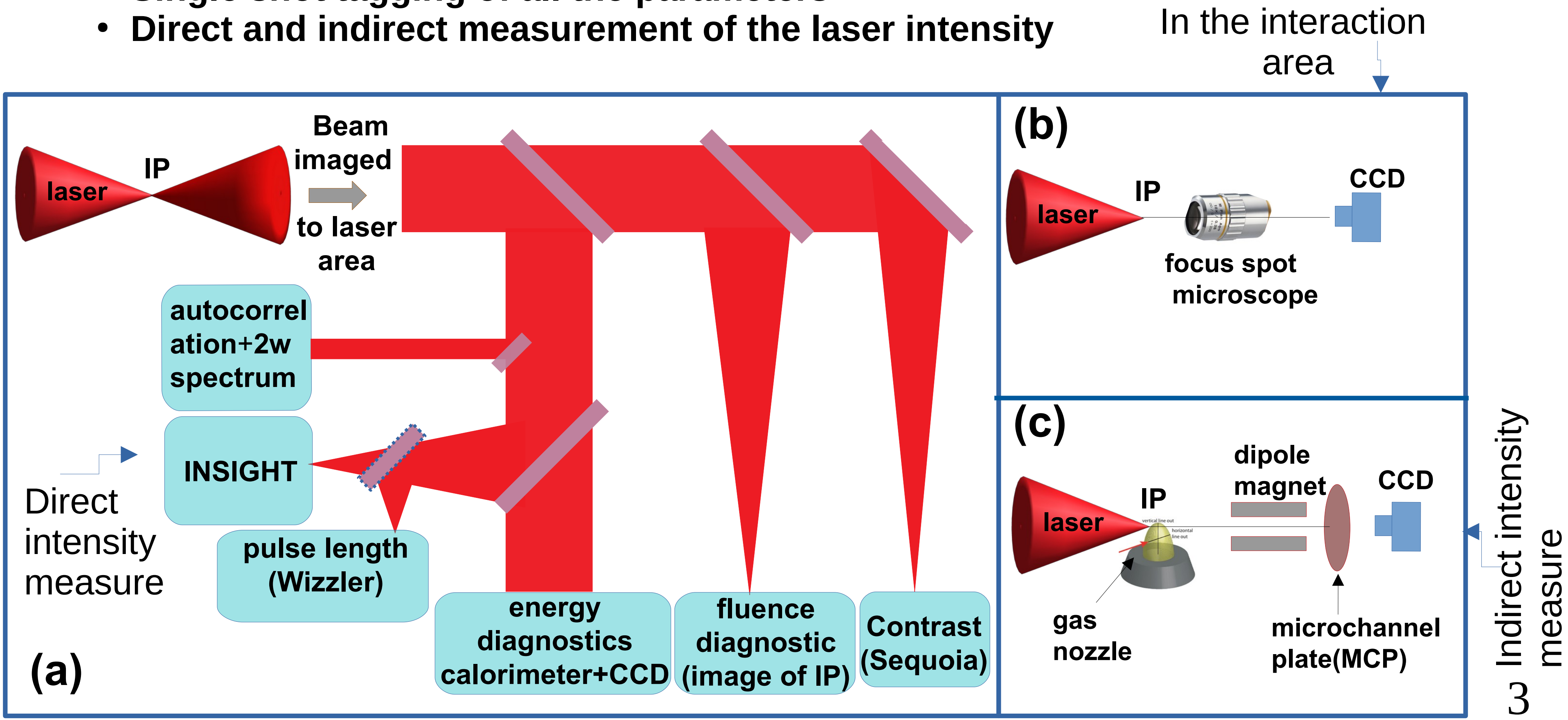
  - **Dimensionless laser strength parameter** $\xi \propto \sqrt{I}$

  - **Nonlinear quantum parameter** $\chi \propto \gamma \, . \, \xi$

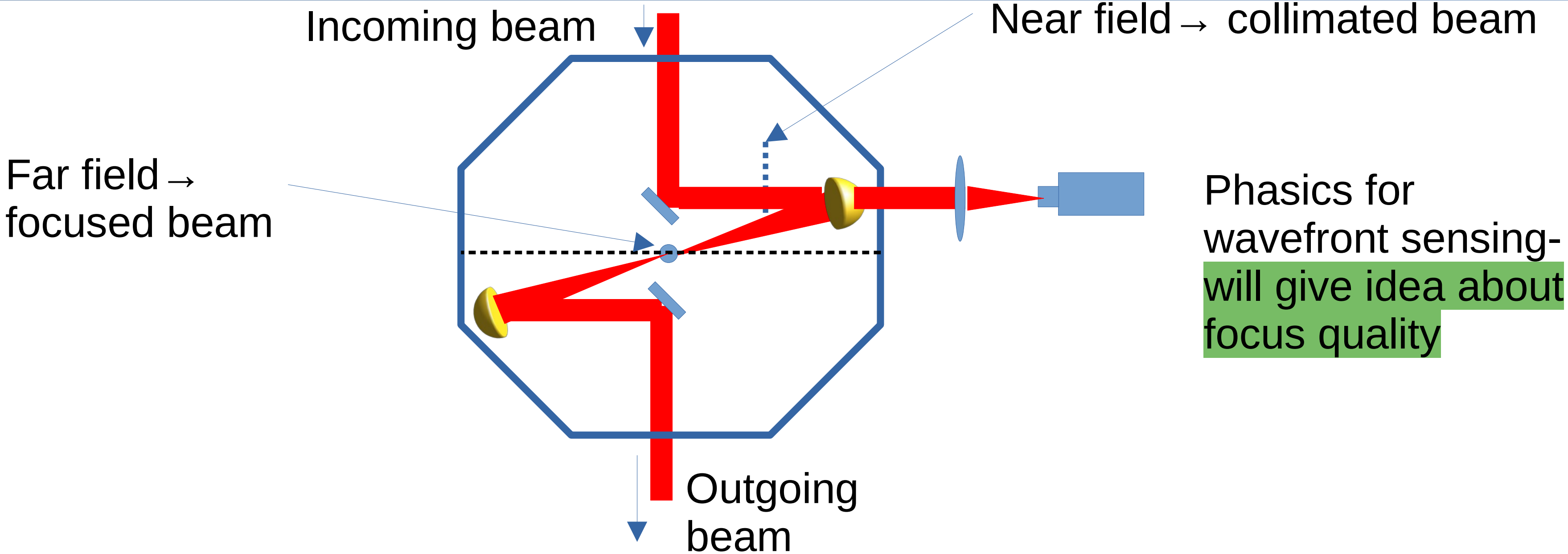
- **As Beate has shown once, 5% inaccuracy in laser intensity may lead up to 40% uncertainty in measured rates of pair production!!**

- **Full diagnostic layout for LUXE- from CDR**

- **Single shot tagging of all the parameters**
- **Direct and indirect measurement of the laser intensity**



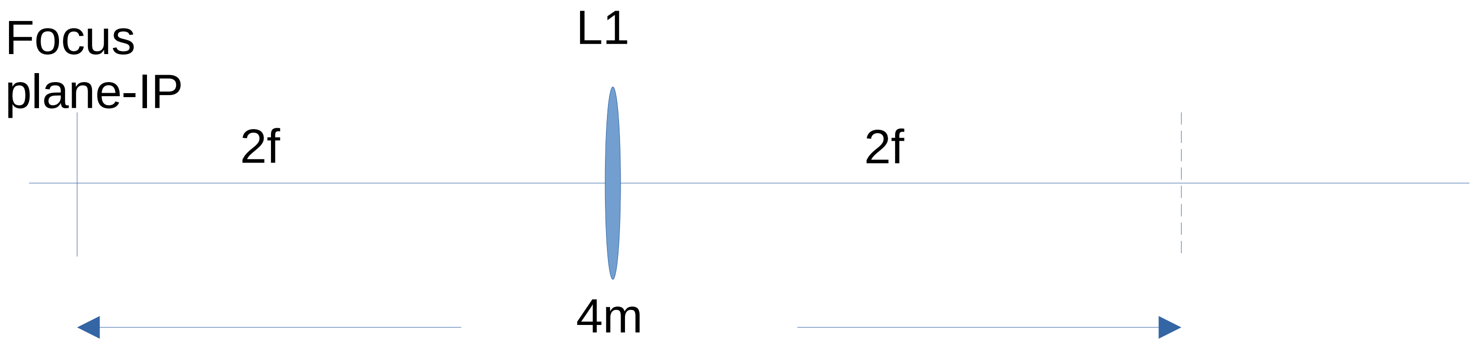
- **LUXE diagnostics “Replica” at Jeti 40**
- **Part I: focusing, recollimation and wavefront sensing**



- OAP f=25cm, with 5cm beam f#5 and with 4cm it could go up to f#6. Then we shall have 7-8µm focus spot
- With f=25cm, we should be able to fit both the OAP on the same breadboard!
- Angle of incidence AOI=15 degree?
- Critical is also the alignment of both OAP without losing overlap with the e-beam
- We can place the Phasics at the focus to record the phase over long time. Then it can be used to correlate with the one measured behind the OAP. Other options would be to use 2 of the same type Phasics simultaneously.

Part II: Relay imaging of the near-field close to the IP- imaging and transport

- **Key challenge to measure all the laser parameters relevant at the right position, ie, at the IP and near the IP. However, in the laser area not in the interaction area.**



$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

When L1 focal length is =1m, 4f is 4m.

- The dashed line is the position of image plane for 1:1 relay case
- We need to use one more lens to collimate the beam. Hence a combination of lens would be used.
- Working on to find out how much space is available and what can we fit there

- **Part III: to implement all the possible diagnostics**

- **Indirect intensity measurements using gas jet**

One can not measure the focus spot with full laser energy directly

- Corresponding electric field strength at the Bohr radius

MKS

$$E_a = \frac{e}{4\pi\varepsilon_0 {a^2}_B}$$ $=5.1\text{x}10^9$ V/m ε_0 permitivity of free space

- Corresponding intensity- matched with the binding strength of the electron

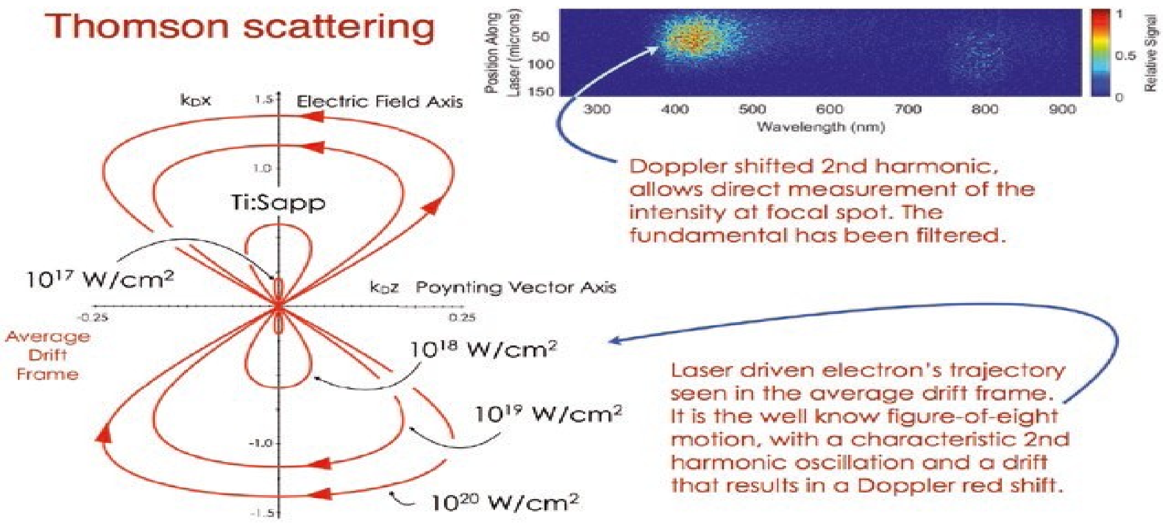
$$I_a = \frac{\varepsilon_0 c {E_a}^2}{2}$$ $\sim 3.51\text{x}10^{16}$ W/cm^2

- Above this intensity any atom will be immediately ionised!!
- In our case, by focusing to few um, we easily reach above 10^{18} W/cm^2.
- This is the reason we have to reduce the energy in the pulse.

How one can measure the intensity- indirectly?

- Intensity as a function of the observed nth harmonic wavelength

$$I(\lambda^{(n)}, \theta; n) = \frac{2\pi m_e c^3}{r_0 \lambda_0^2 (1 - \cos\theta)} \left(\frac{n\lambda^{(n)}}{\lambda_0} - 1 \right)$$



- **Electron dynamics in electromagnetic field: famous 'Figure-of- eight'**

https://www.laserlab-europe.eu/news-and-press/newsletter-archive/issue-28

Vol. 27, No. 21 / 14 October 2019 / Optics Express 30025

Ponderomotive force- effect on electron dynamics

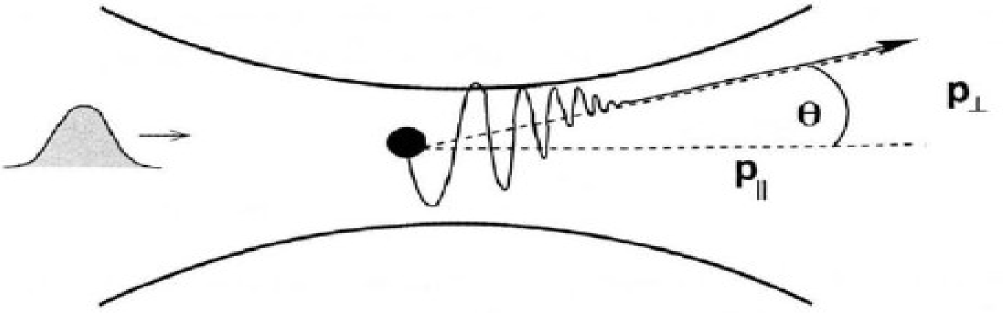
- **Non-linear, Ponderomotive force in non-relativistic regime**

$$F_p = -\frac{1}{4}\frac{e^2}{m\omega^2}\nabla {E_0}^2$$

- **Non-linear, Ponderomotive force in relativistic regime**

$$F_p = -m_0 c^2 \nabla\gamma$$

- **Relativistic electron motion in laser focus**



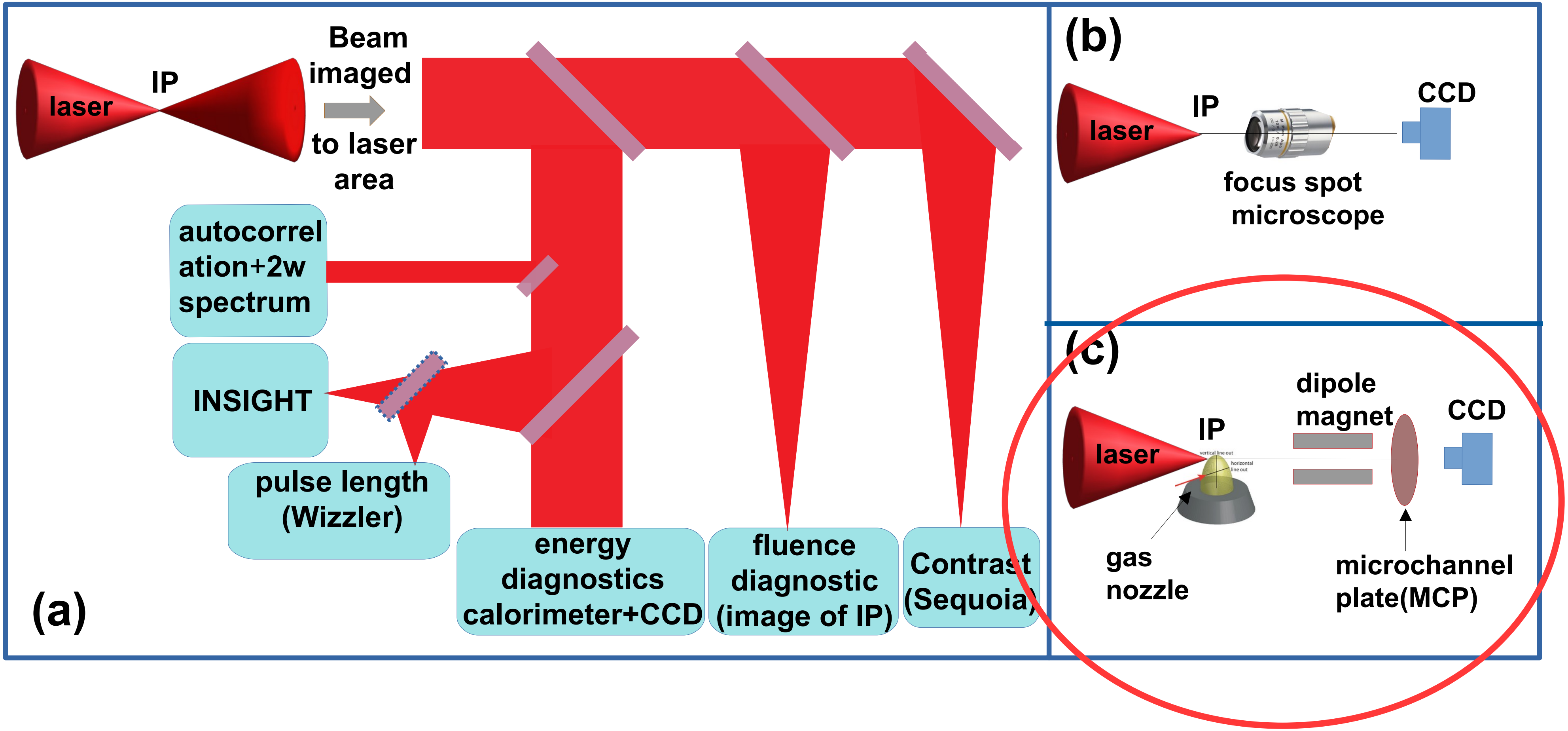
- **Emission angle of electron**

$$\tan\theta = \frac{p_\perp}{p_\parallel} = \sqrt{\frac{2}{\gamma - 1}},$$

$$\cos\theta = \sqrt{\frac{\gamma - 1}{\gamma + 1}}.$$

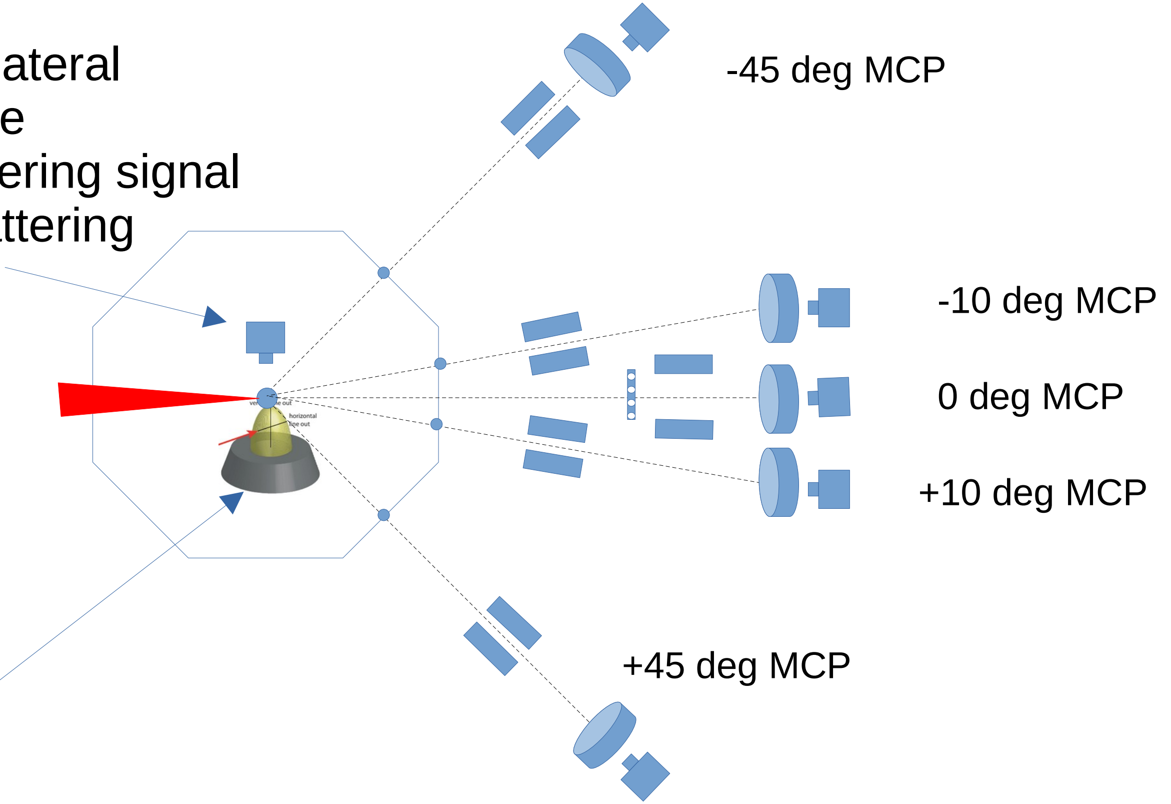
From Gibbon et al

- **Full diagnostic layout for LUXE- Fig (c)**



- **Experimental planning for the indirect intensity measurements : combining both methods**

- Microscope objectives in lateral direction and above nozzle
- to capture Thomson scattering signal together with electron scattering measurements



- requires gas jet to provide electrons

Summary:

- **Work in progress**
- **Still need time to properly set up each and every diagnostics**