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Design of High Gradient Laser Plasma Accelerating Structure (WP3) Plasma diagnostics

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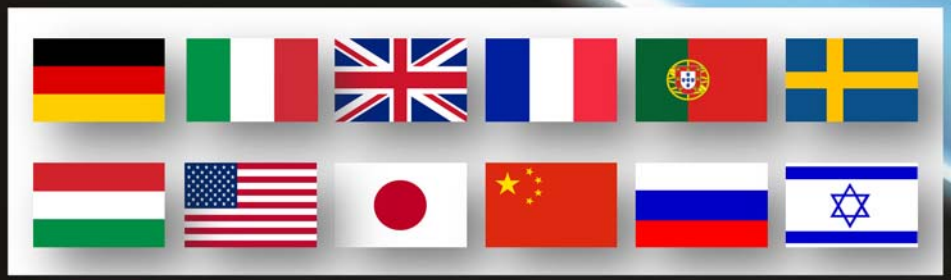

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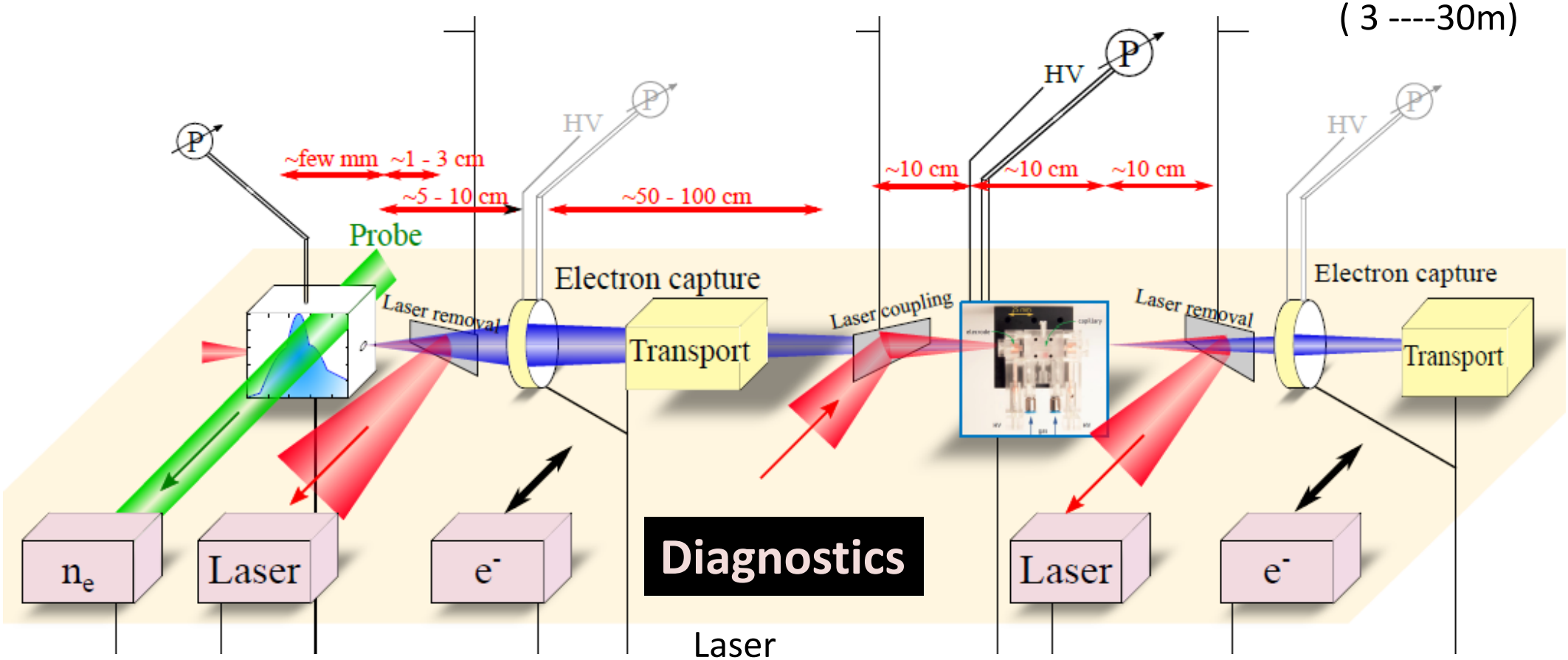
LPI + LPA conceptual scheme



Plasma Density Cavity (Ep)

Laser Energy Spectrum pointing

Electron parameters

Laser Energy Spectrum pointing

Plasma Density Cavity (Ep)

Laser Energy Spectrum pointing

Electron parameters

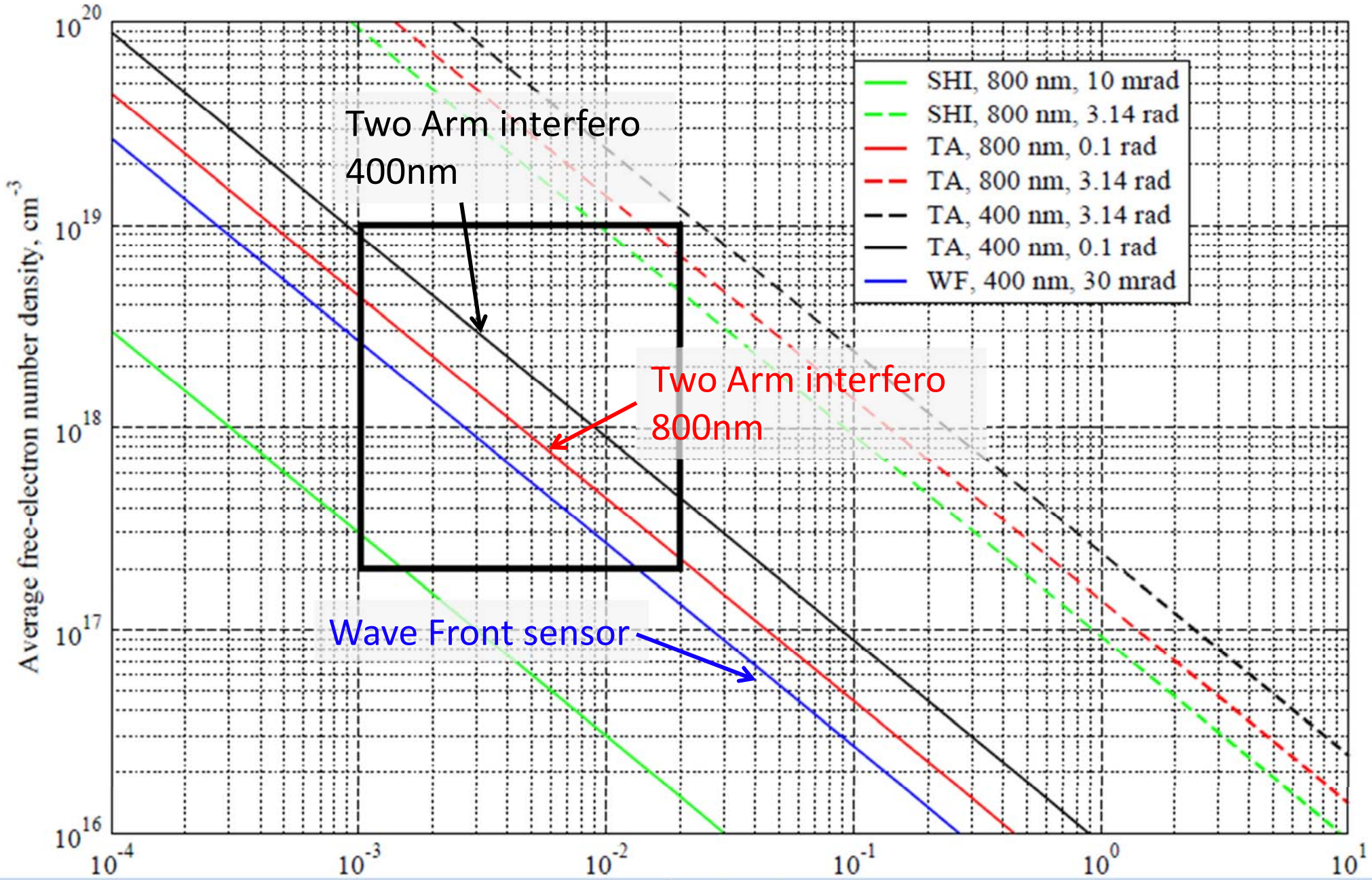
Use of Diagnostics

- **Alignment**, A : in the preparation phase or start-up after an interruption of operation.
- **Tuning**, T : to monitor plasma parameters while tuning the accelerator, changing operation mode or optimizing electron beam parameters.
- **Operation,** O: to monitor plasma parameters for measuring quality (reproducibility and stability), and detect any potential deviation or trouble during operation.

Type of plasma diagnostics

- Measurement of **Plasma density**, integrated over a given volume
  - Typically deduced from the phase variation of a probe beam (interferometry or wavefront analysis)
  - Transverse plasma size 10 µm -1mm
- **Plasma wave amplitude**
  - Average value can be deduced from the spectral modulation of the laser beam (red shift) over the propagation distance
  - Longitudinal plasma size 1-30cm

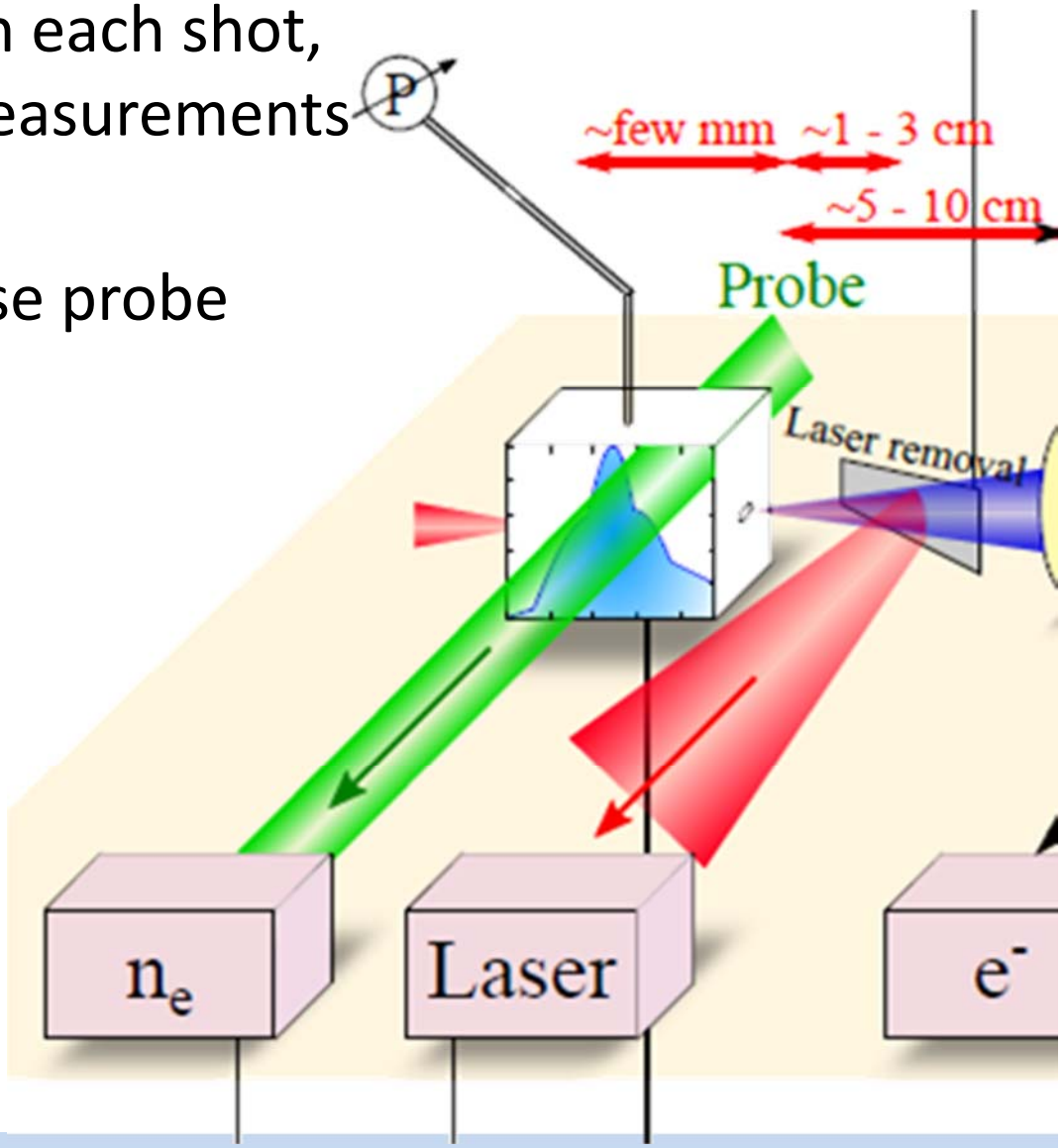
Capability of interferometric methods for LPI



LPI diagnostics

- **Plasma density max value** in the range 10^{17}-10^{19} cm^{-3}
  - Measurement of max value on each shot, profile restituted by offline measurements and fluid simulations
  - Interferometry using transverse probe

- **Laser parameters**
  - Input parameters as reference on each shot
  - Radiation reflected from the 'laser removal' component can be analysed (energy distribution, duration, spectrum, pointing,...) to monitor reproducibility of interaction

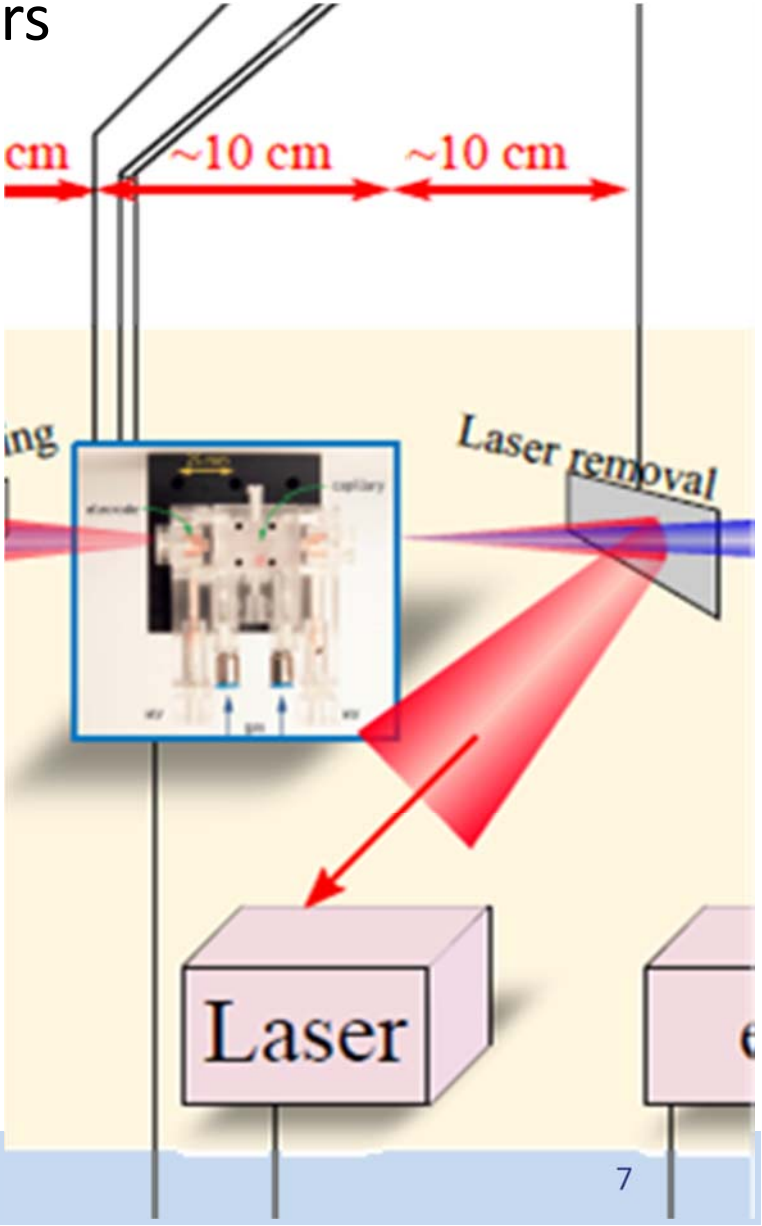


LPA diagnostics

- **Plasma density max value** in the range 10^{17}-10^{18} cm^{-3}
  - Pressure and discharge (if any) parameters
  - Interferometry using transverse probe(s)

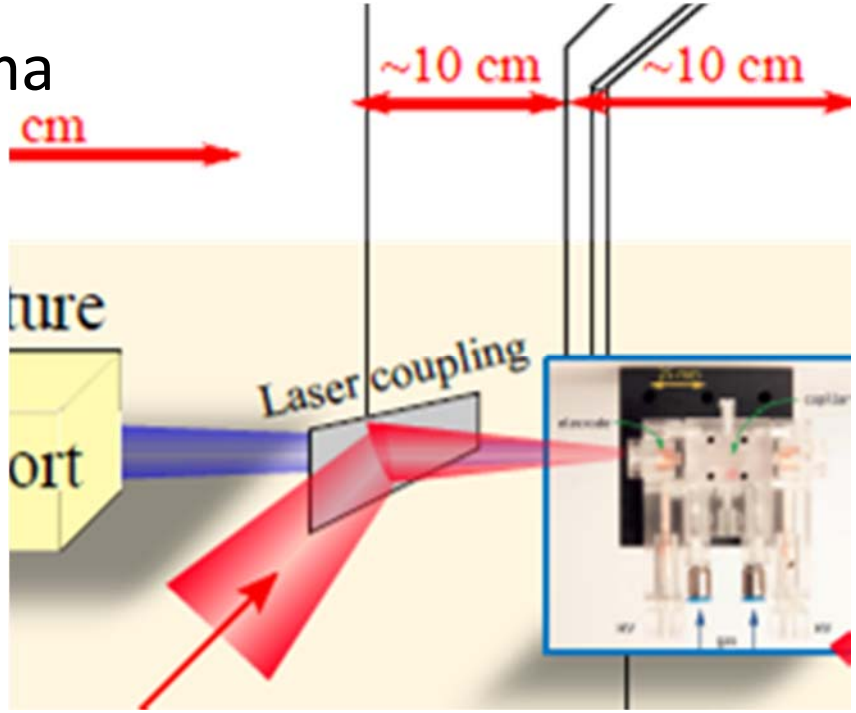
  at different positions along propagation

- **Laser parameters**
- Input parameters as ref on each shot
- Radiation reflected from the 'laser removal' component can be analysed:
  - Mode analysis => guiding quality
  - Spectral analysis =>plasma wave amplitude



Laser Plasma coupling diagnostics

- **Plasma wave guide** and laser need to be positioned on the same axis
  - Laser imaging through coupling component for position reference (leaky plasma mirror)
  - Imaging system for entrance of plasma waveguide (laser position relative to entrance hole)
  - **Good location for laser and electron timing diagnostic (e.g. EO detection)**



Summary

- A set of diagnostics for monitoring plasma density and plasma wave amplitude can be designed from existing techniques for alignment, tuning and operation

Contributions to diagnostics in WP3

- **CNRS** : **B. Cros**, T Audet
- **ICL** : J. Cole, **Z. Najmudin**
- **INO**: F. Brandi

Additional slides

Plasma target characteristics have been compared

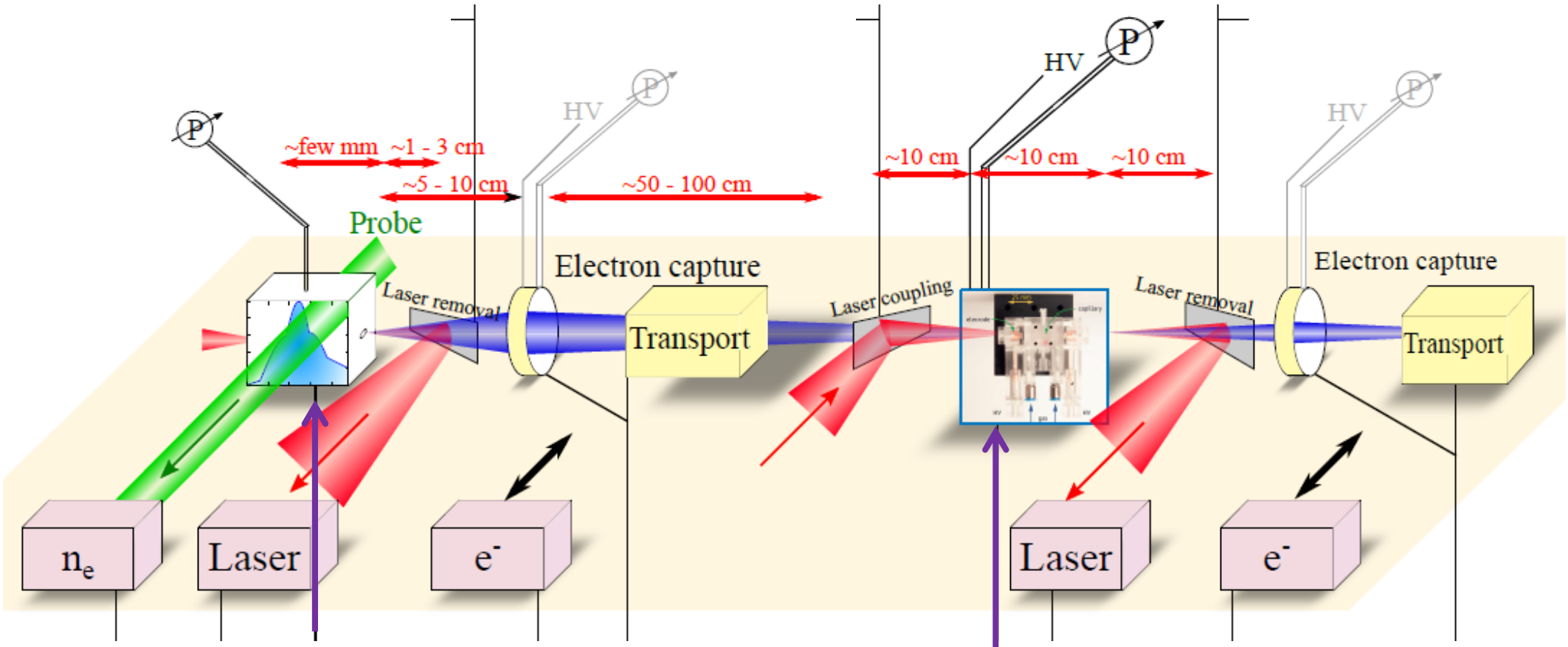
Target type	Length mm	n_e value cm^{-3}	n_e tailoring	n_e stability	rep rate	life time
Gas jet	< 20 self-foc.	10^{18}	multiple jets	turbulent flow	10 Hz	> 24 h
Gas cell	> 1 self-foc.	10^{17} - 10^{19}	machining	gas feed dependent	10 Hz	laser quality dependent
Plasma channel HE	< 30 guiding	$(1-5) \times 10^{18}$ parabolic	similar to gas jet	laser quality dependent	10 Hz	>24h
Plasma channel discharge	$10-90$ guiding	5×10^{17} - 10^{19} parabolic	multiple gas feed	discharge dependent	10 Hz	laser quality dependent
Cap tube	10-1000 guiding	$(0-5) \times 10^{17}$ homogeneous	multiple gas feed	gas feed static	10 Hz	laser quality dependent

LPI and LPA parameter range

- LPI similar for 150MeV to 400MeV, Gas cell
- LPI at 1GeV, guiding needed →channel
- LPA in QL regime, guiding needed
- Use of 2 stages allows for electron selection with transport system and beam shaping

Parameter	LPI 150MeV	LPI 400MeV	LPI 1GeV	LPA 5GeV
n_e [$10^{18}cm^{-3}$]	3 - 8	3 - 5	1 - 6	1 - 3
L_{plasma} [mm]	0.6 - 1.5	0.8 - 1.6	9 - 30	250 - 1000
L_{grad} [mm]	0.3 - 0.5	0.6 - 0.8	0.9 – 2.1	8.5 – 14.8
I_{max}[$10^{18}cm^{-3}$]	4 - 17	15 - 43	3.1 - 32	2 - 9
a_0	1.4 - 2.8	2.6 – 4.5	1.2 – 3.9	1 - 2

LPI + LPA conceptual design



LPI

1. Gas cell

2. Cap discharge

3. Gaz jet

LPA

Plasma channel

Cap discharge / Laser generated

SAC recommendations for WP3

Rec9. *SAC recommends* ***decreasing this number [of configurations under investigation]*** *in the short term with appropriate metric and thereafter to perform tolerance studies for the main parameters.*

Rec 10*. SAC recommends detailed evaluation of* ***plasma & laser diagnostics****, laser beam/electron beam alignment and synchronization for the CDR.*

Rec11*. SAC recommends performing a* ***thermal study of the plasma cell*** *considering the significant increase of laser average power and to prototype the plasma cell according to final design for any activity following the design study.*

Rec 9:

LPI & LPA selected

Joint Exp in preparation for stability study of LPI

Rec 10: plasma diagnostics described MS Rep 3.4

Laser/e- alignt and synch : to do, interaction WP4 & 5 this week

Rec 11: to do

Need 10Hz facility for testing prototypes (current operation at 0.03 Hz)