Long Focal length Area (LFA)

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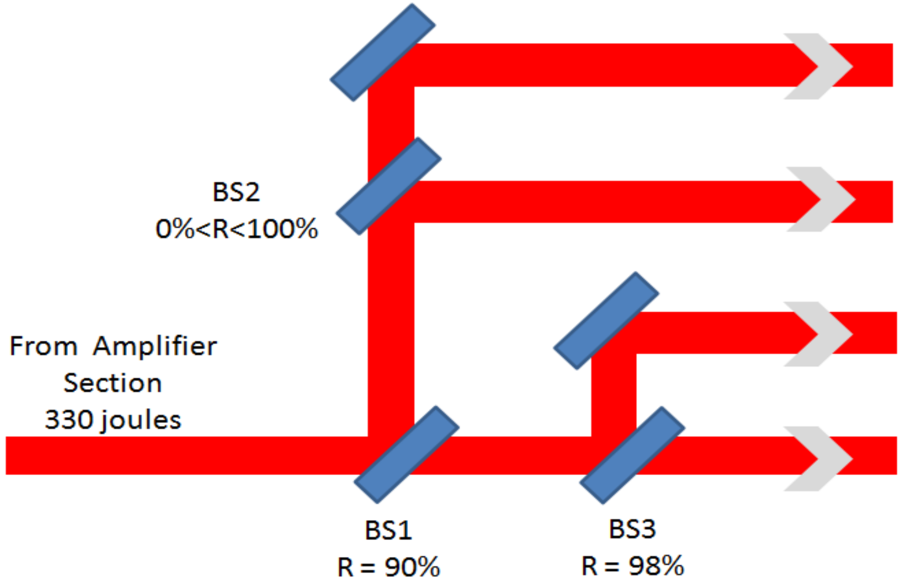
- **4 independent beams, energies variable in steps**



10PW:15fs-few ps / 150,75,50,25J

«creation» beam: 200J uncompressed

1PW: 15fs-fewps / 15,10,5, 1J

«probe»: <20fs / 250mJ

- **10PW beam -> 4PW in first years**
- **pointing stability**
- **beam synchronization**
- **«haute» cadence : 1 tir/min**

Cilex Apollon

Objectives for Laser Plasma Acceleration in the frame of CILEX

scientific advisory committee 2015, B. Cros

- Study the feasibility of a laser plasma accelerator scalable to high particle energy

  -> Combine high gradient methods and meter scale stages

- Implement a test facility for laser plasma acceleration studies: build a community of physicists
- Develop a reliable relativistic electron source for applications: build a community of users

Work is organized in 3 phases

scientific advisory committee 2015, B. Cros

- **PHASE 1: 2013-2016**
  Design experiments in Long Focal-length Area (LFA)
  - Research program on satellitefacilities (LOA,UHI100)
  - Conceptual & technical design of the experimental set-up (CILEX)
  - Procurement & implementation of equipment in LFA
- **PHASE 2: 2017-2018**
  Commissioning of the 1st PW beam and facility through the mechanism of LPA in the bubble regime
  - Validation of laser specification ($I < 10^{20}$ W/cm^2, $a_0 < 7$)
  - Comparison to scaling laws and exploratory experiments
  - Injector optimization
- **PHASE 3: 2019-2021**
  Develop a two stage Laser Plasma Accelerator (Injector/accelerator)
  - Electron beam transport , focusing, synchronisation, and injection into a plasma wave over a long distance

3 main tasks identified for Phase 2 and preparation of phase 3

scientific advisory committee 2015, B. Cros

- **T1. Exploratory experiments using a single beam**
  - Validate scaling laws & commission the facility (laser parameters, experimental area)
  - Explore new regimes to produce high quality electron beams in the few GeV range
- **T2. Optimize injector (1PW):**
  - >100pC charge electron bunches in the range 50-300MeV, that can be focused at the entrance of the 2^{nd} stage.
- **T3. Develop and implement the equipments necessary to**
  - Characterize electron bunches (energy and spatial distribution)
  - Synchronize electron bunch and laser beam
  - Transport electron bunches at the entrance of the second stage
  - Guide the laser beam over large distances (0.1-1 m)

Task1. Explore ways to produce high quality electron bunches in the few GeV range

- **Using new injection schemes**
  - Shock injection, with or without ionization assistance
  - Electron energy increase boosted in density ramp
- **Expected from scaling laws** **Lu PRSTAB 10, 061301 (2007):**

  for 15 J laser at 0.8 micron wavelength, 45 fs duration, and with $a_0 \sim 4$, e-bunch ~ 100 pC around 2-2.5 GeV
- **Exploit the large bandwidth of the laser pulse**
  - to study effects of the chirp, of the temporal profile, and of the group delay dispersion (GDD)
  - by controlling the GDD (linear chirp) and/or the Third Order Dispersion (asymmetric temporal profile)

Task 2. Optimize the injector for Apollon operation parameters

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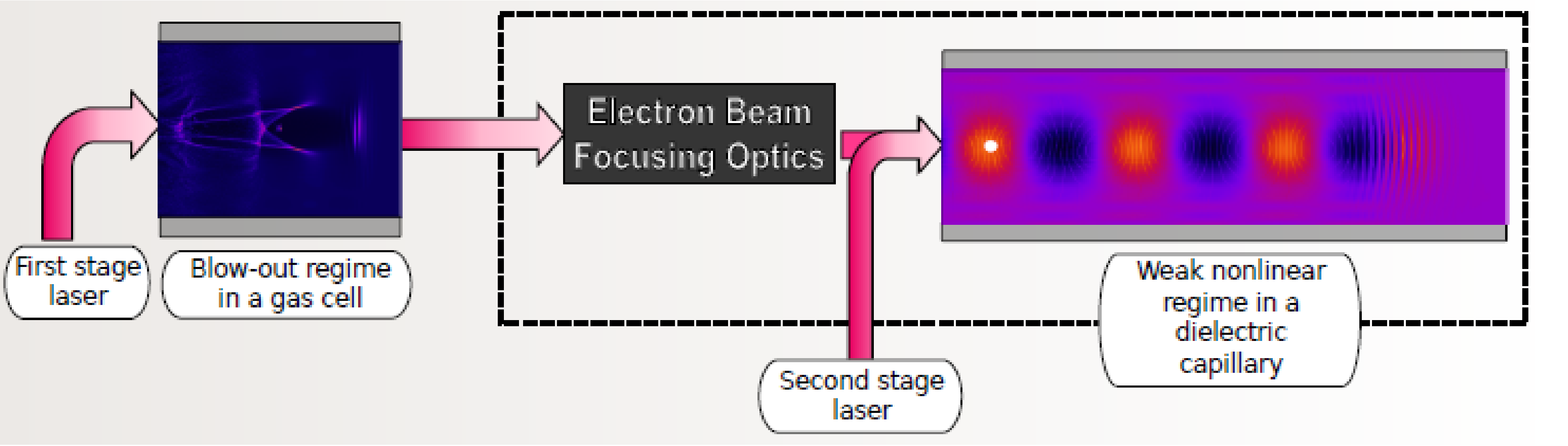


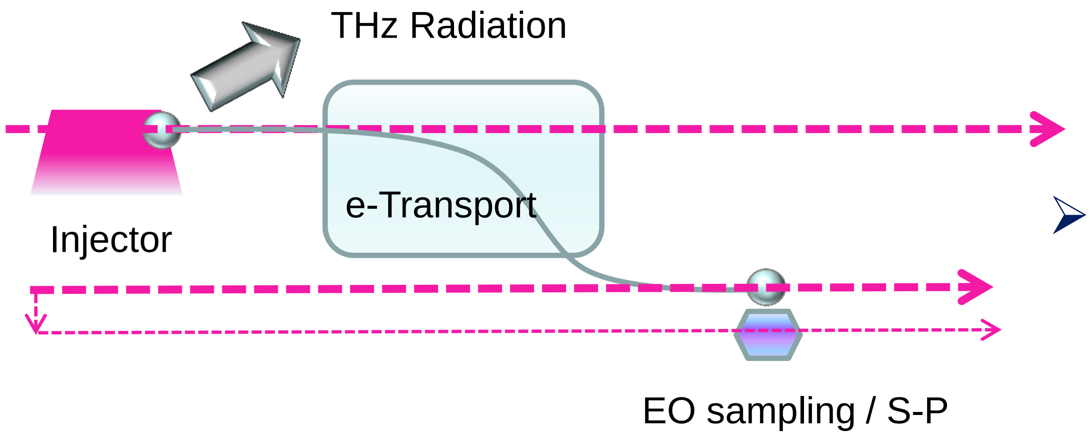
Requirements to define the injector

- Compact and robust scheme, easy to implement
- Bunches with energy in the range 50-300MeV
- Divergence <10mrad
- Charge larger than 10pC, at the selected energy E_{inj} +/- 10%

T3. Preparation of 2-stage acceleration: development and implementation

scientific advisory committee 2015, B. Cros

- **Transport electron bunches** at the entrance of the second stage
- **Synchronize electron bunch and laser beam** / measure bunch duration



- Non destructive methods, résolution a few10 fs (50 fs on arrival time)
- Electro-optical sampling: THz transition radiation at plasma exit, Coulomb field or Smith-Purcell radiation at accelerator entrance

- **Guide the laser beam** over large distances (0.1-1 m)
- **Characterize electron bunches** (energy and spatial distribution)

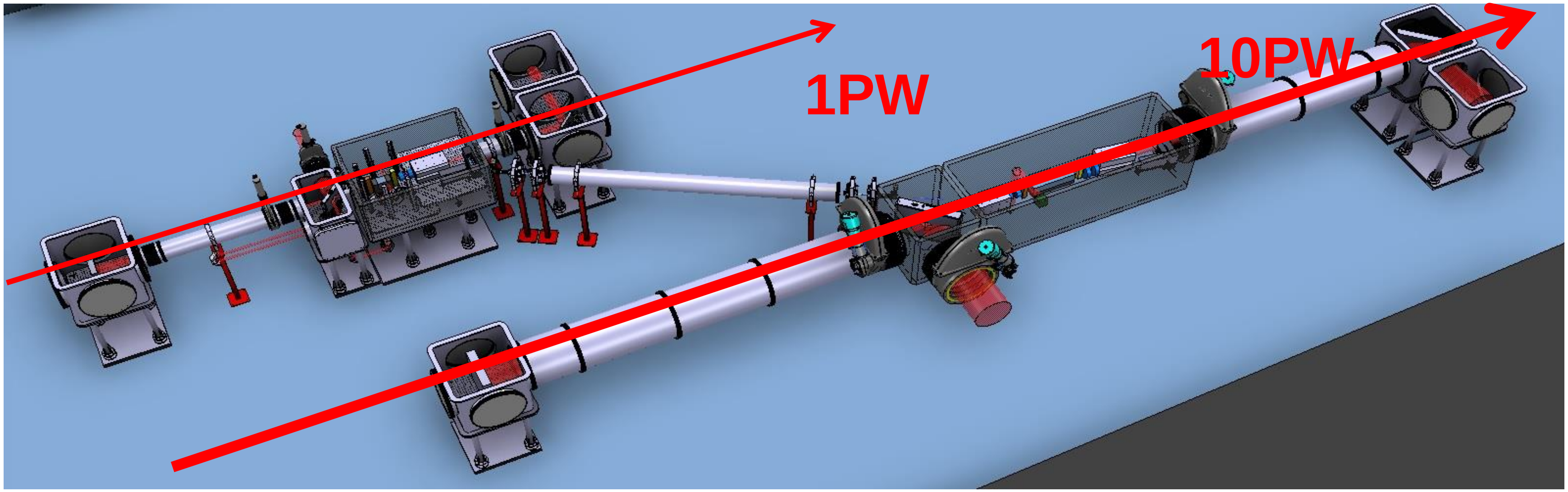
Tentative schedule

scientific advisory committee 2015, B. Cros

RUN	2016				2017				2018				2019				2020			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Installation																				
e- diagnostics																				
1PW exploratory																				
1PW injector																				
e- synchronizatº																				
e- transport																				
4PW guiding																				
2 stage acceleratº																				
TOTAL runs/year	-	-	-	1	-	-	-	3	-	-	-	5	-	-	-	6	-	-	-	6

LONG FOCAL AREA: *baseline design*

- **2 experimental areas IA1 (10PW) and IA2 (1PW)**



- **for each interaction area (IA)**
  - laser transport up to focusing, with vacuum system
  - two focal length focusing mirror per IA, with vacuum system
  - 2 interaction chambers, with vacuum system
  - 2 gas target instrumentation (jet/cell+target platform+feed)
  - 2 simple electron spectrometers (Q^2D or Q^3D):
  - 1 simple electron transport line IP2->IP1 at fixed energy

Conceptual design goals for LFA

- **fulfill experimental program defined by physics WGs e– and X**
  - ensure efficient use of available laser up-time
  - incremental design of setup (e.g. multistage e– acceleration)
  - commissioning of diagnostics in satellite facilities
- **get the most of each laser shot (APOLLON 1 shot/min)**
  - favor non-destructive and non-obstructive diagnostics
  - simultaneous and resident e– and X-ray diagnostics
  - reliable and flexible data acquisition infrastructure
- **flexibility of setup, openness to national and international teams**
  - provide resident, operational diagnostics beam alignment system
  - accommodation of non-resident diagnostics and setups
  - provide secondary beams (e–, X, gamma) for applications

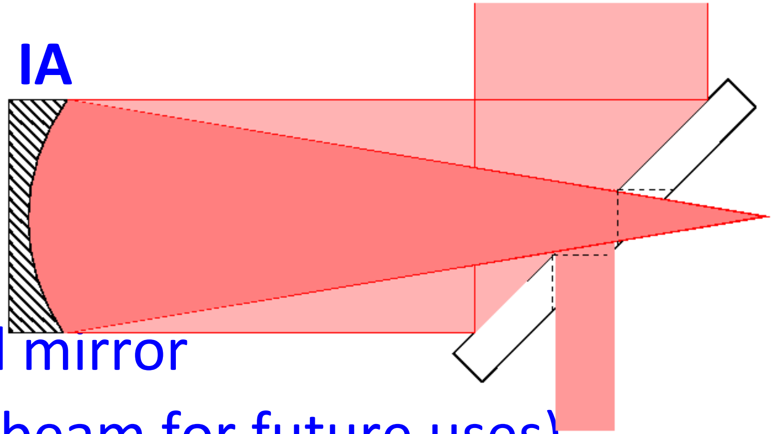
important options for future evolutions…

… but not considered in baseline conceptual design

- **external injection (2 beams) with F4 “probe” beam, non-zero angles**
- **experiments with F1 et F2 in interaction area IA1**
- **non-spherical focusing optics diagnostics**
- **sophisticated electron diagnostics (e.g. undulator)**
- **head-on collisions of electrons (from IA2) et laser 10PW (F1) in IA1**

general design choices for LFA

- **2 distinct and independently exploitable interaction areas (IA)**
- **2 multi-usage, flexible experimental vacuum vessels for plasma sources of lengths <10cm (IA2) and <50cm (IA1)**
- **12m of dump tunnel (N) and 0m of LINAC tunnel (S) accessible**
  - accelerated electrons and lasers propagate south
- **focusing with spherical mirrors in each IA**
  - rather than OA parabolas:
    cheaper, easier to align, variable f
  - use of beam through hole in pierced mirror
    for diagnostics (reserve F4 “probe” beam for future uses)

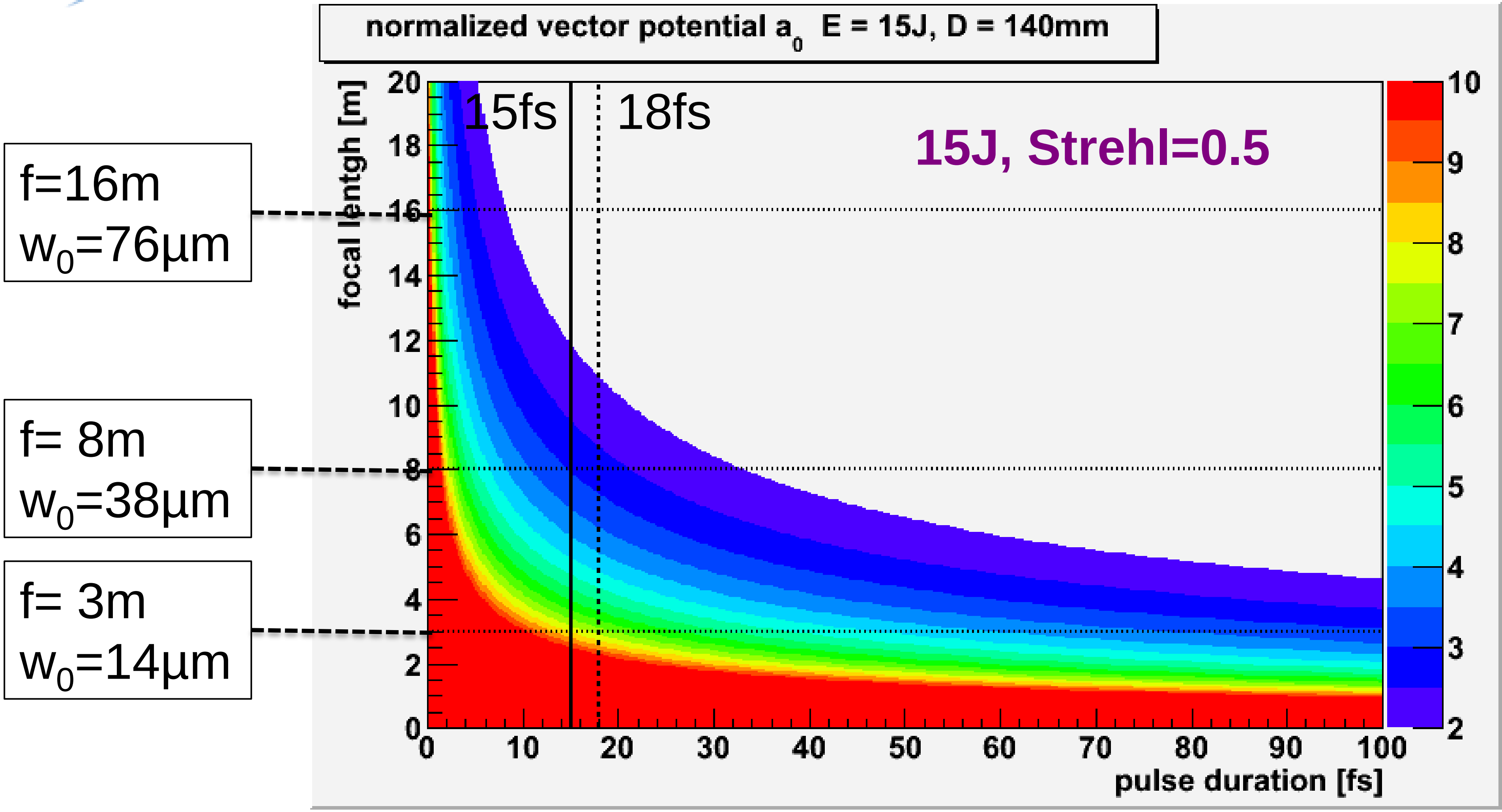


- **simple electron transport line from IA2 to IA1 (fixed momentum)**

where is the flexibility?

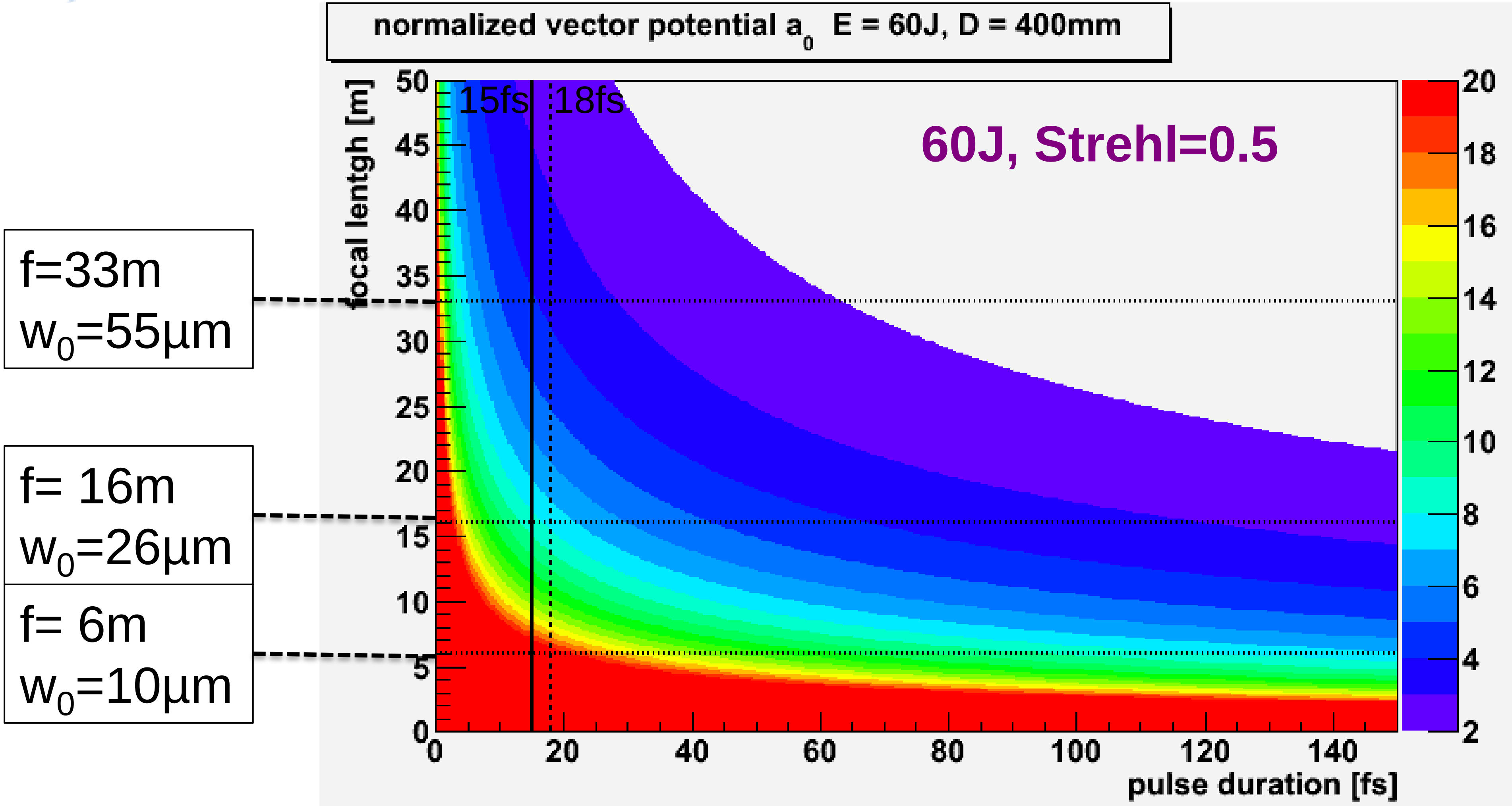
- **2 independent experimental areas**
  - commissioning/qualification of F1 will not exclude or impact physics experiments with F2 in IA2
  - preparation of multi-stage experiments in parallel with F2
- **variation of focal length : I_0 w_0 matching**
  - F1 ("10PW"):fmin = 8m, 16m, 32m Ø=400mm
  - F2 ("1PW") :fmin = 3m, 8m, 14m Ø=140mm
- **modular chambers, rectangular, modifiable covers (ports)**
- **facilitated cohabitation of diagnostics (e^-, X, optical)**
- **possible plasma lengths F2: 0-10cm, F1: 0-50cm (or more)**
- **accommodate a variety of plasma targets (jets, cells, capillaries, discharges)**

scénarios expérimentaux pour F2 (Ø140)



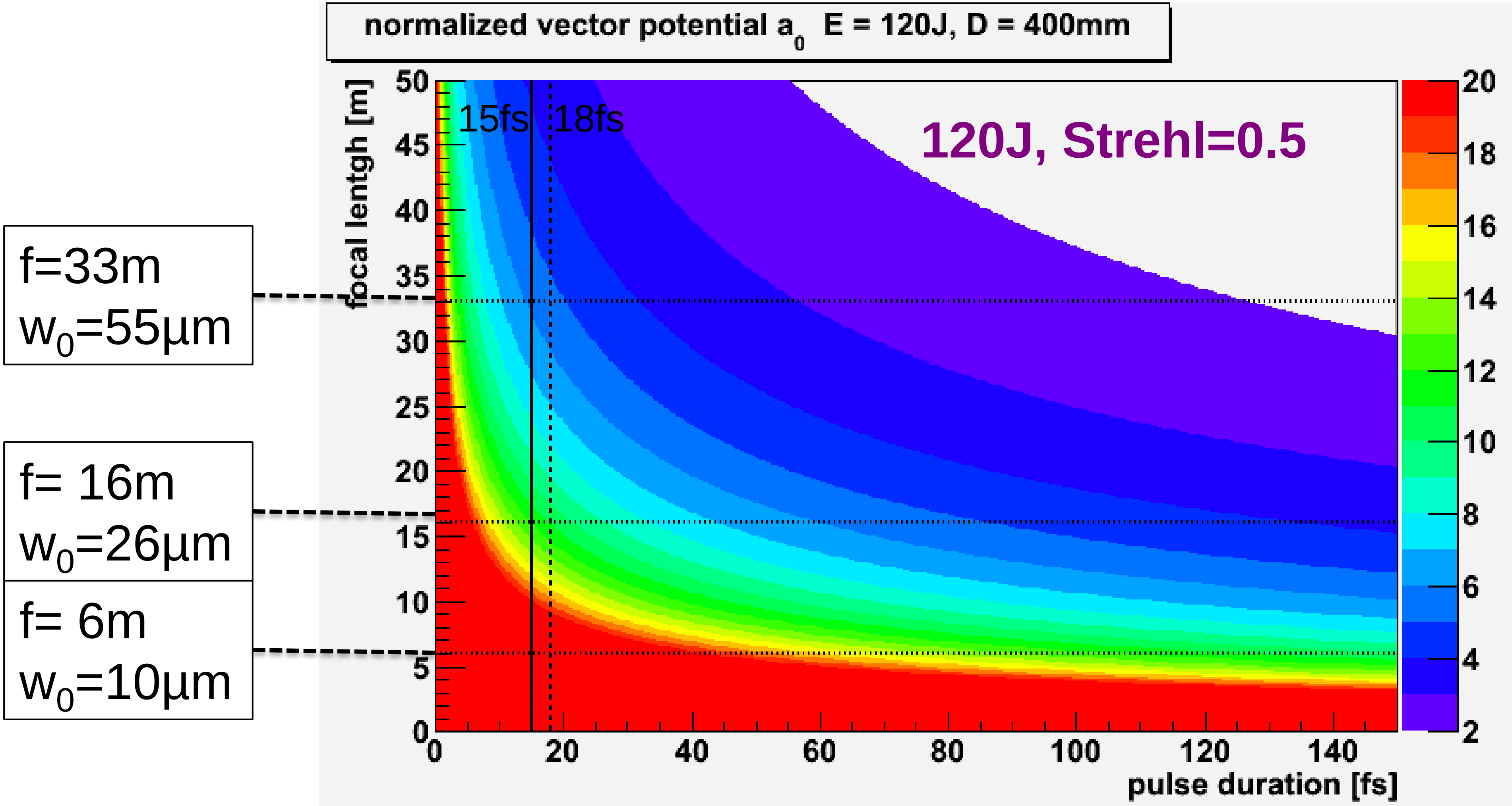
- **longueur focale 3m : a_0<7, n_e ~ 4 10^{18}cm^{-3} ($k_P w_0 \sim 2\sqrt{a_0}$)**

scénarios expérimentaux pour F1 (Ø400)



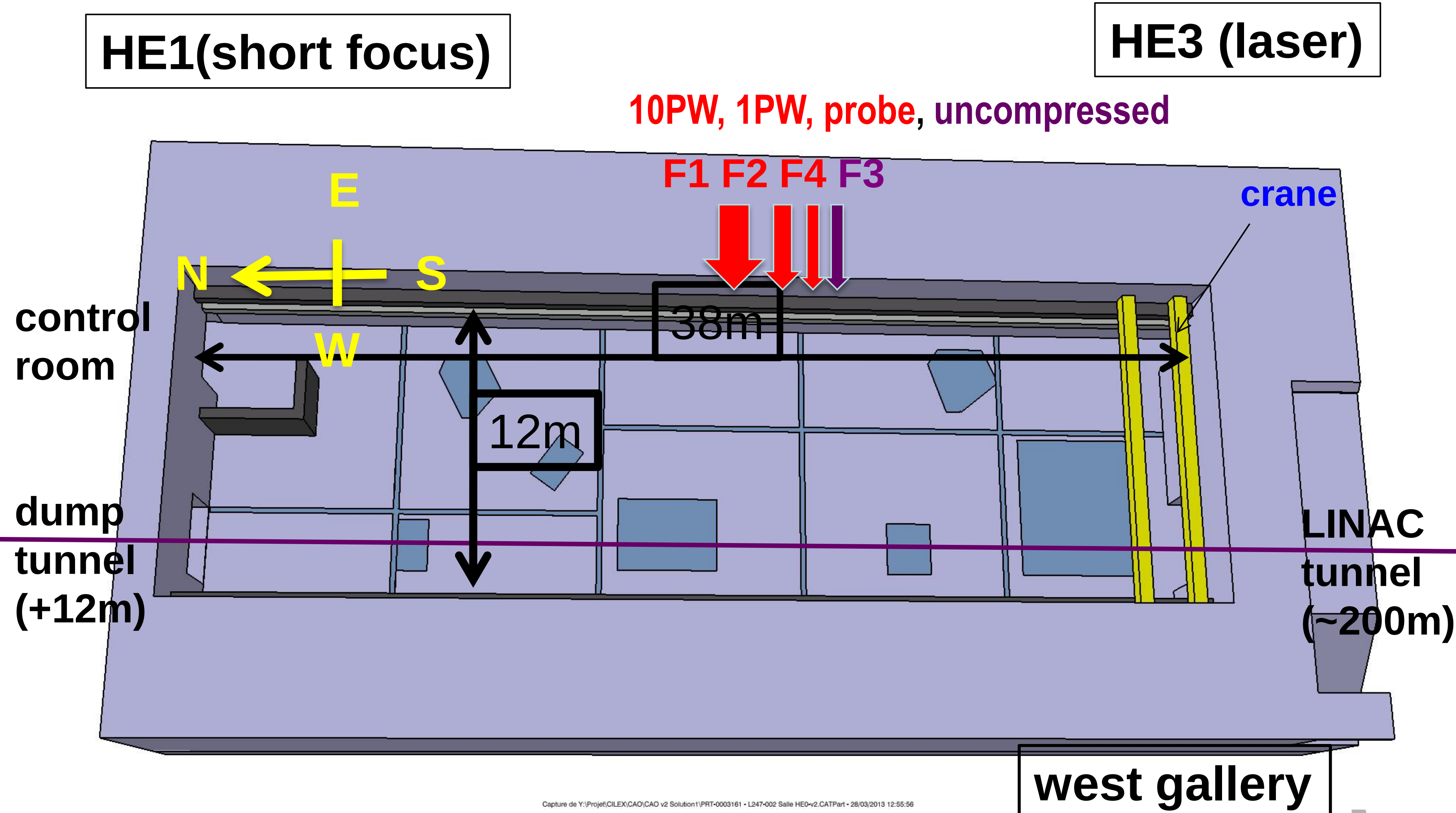
- longueur focale 3m : $a_0<8$, $n_e \sim 1.4\ 10^{18} cm^{-3}$ ($k_P w_0 \sim 2\sqrt{a_0}$)

scénarios expérimentaux pour F1 (120J)

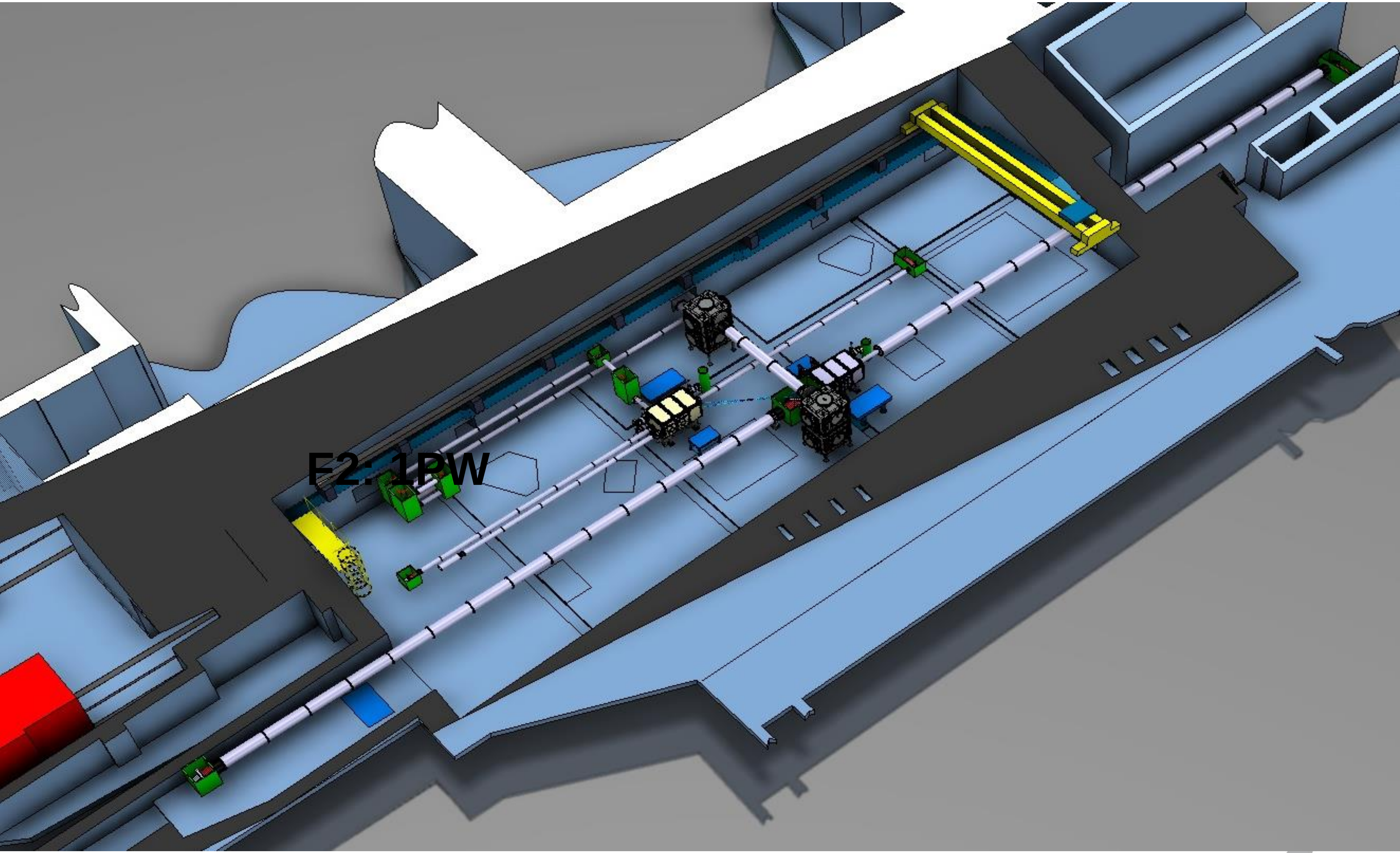


- 33m focal length: $a_0<6$, $n_e \sim 2.8\ 10^{17} cm^{-3}$ ($k_P w_0 \sim 2\sqrt{a_0}$)

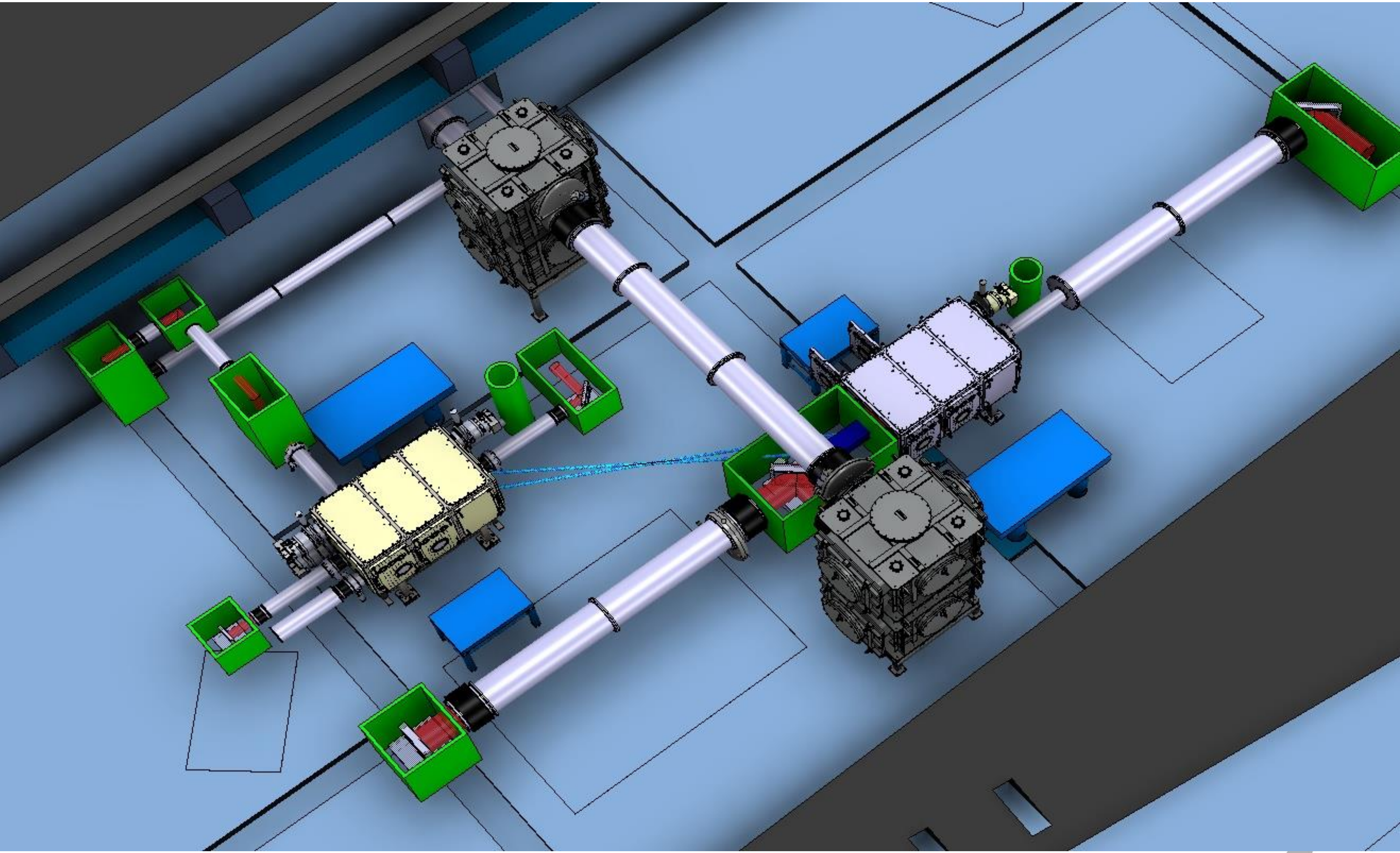
Reminder: Experimental Hall HE0



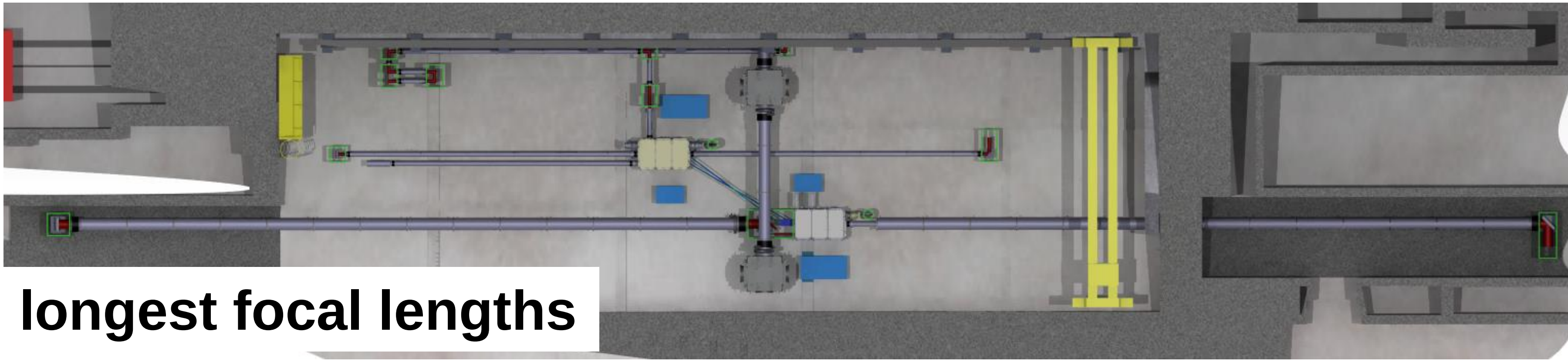
GENERAL LAYOUT (highest focal lengths shown)



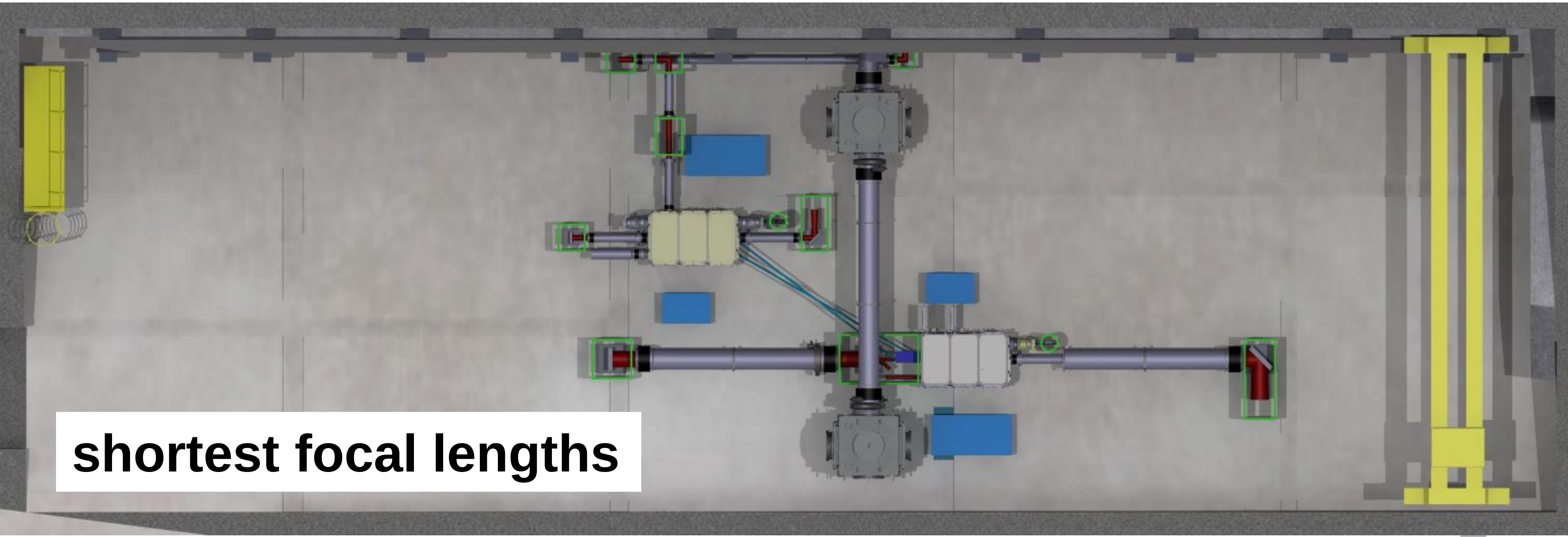
GENERAL LAYOUT (smallest focal lengths shown)



GENERAL LAYOUT (top view)



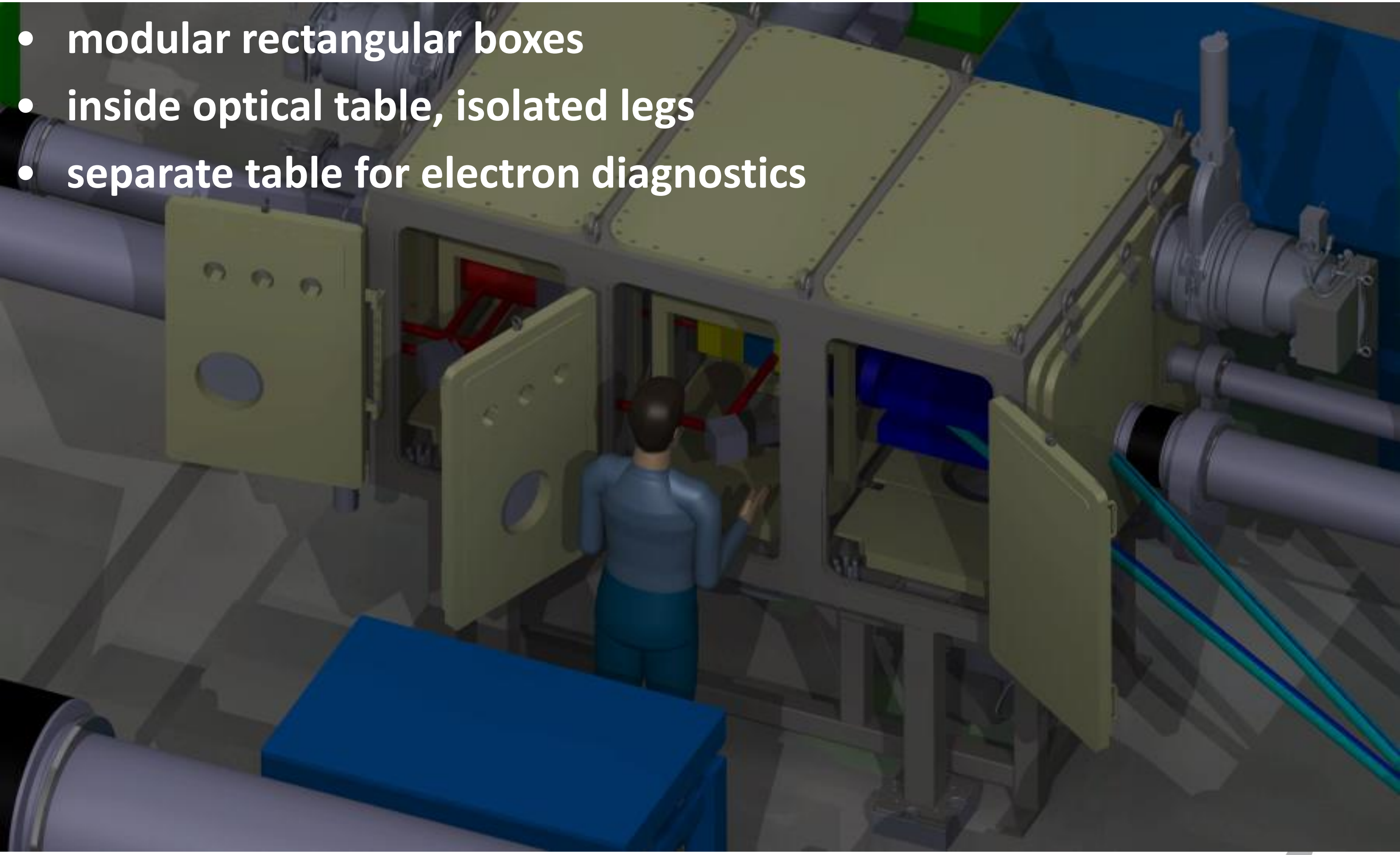
longest focal lengths



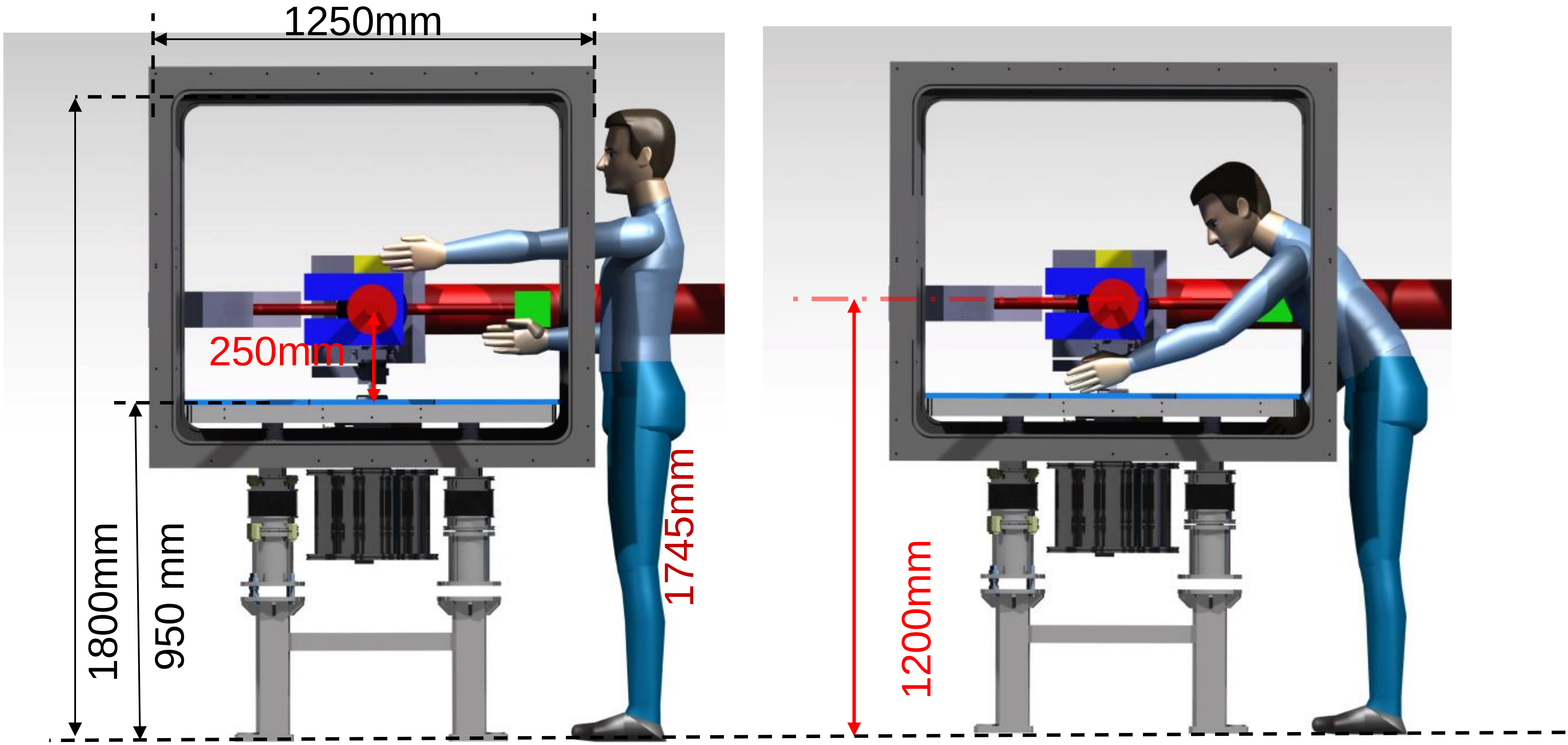
shortest focal lengths

Interaction chambers, here 1PW beam (F2)

- **modular rectangular boxes**
- **inside optical table, isolated legs**
- **separate table for electron diagnostics**

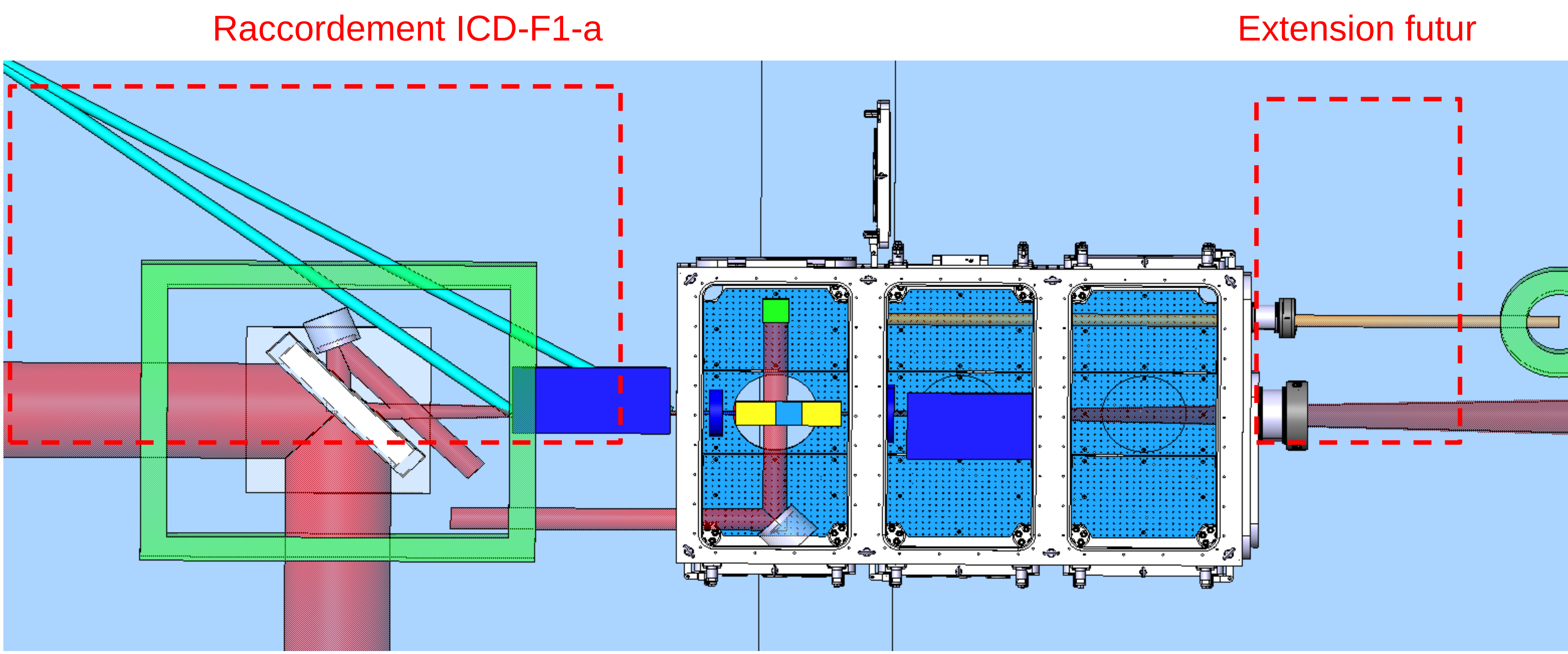


interaction chambers : access +ergonomy

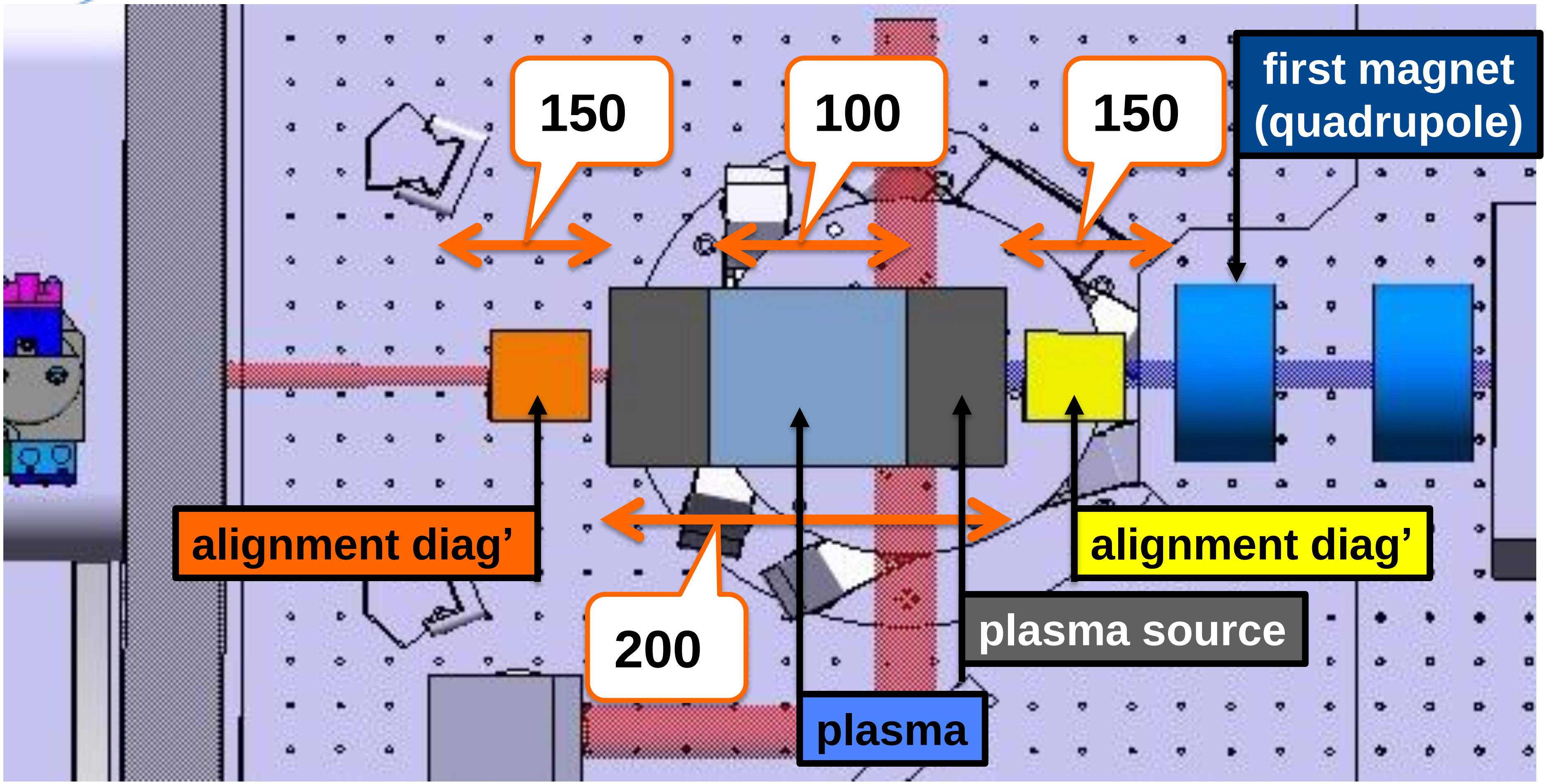


- access from top (lids) and bottom (doors, flanges)
- dais 40-50cm for top access (ergonomy)
- laser beam 1150mm above floor level

interaction chamber: here 10PW beam (F1)



interaction areas: space reservations (here: IA2))



- **IA2: plasma length <10cm, source device length <20cm**
- **distance plasma exit – first magnet as small as possible!**

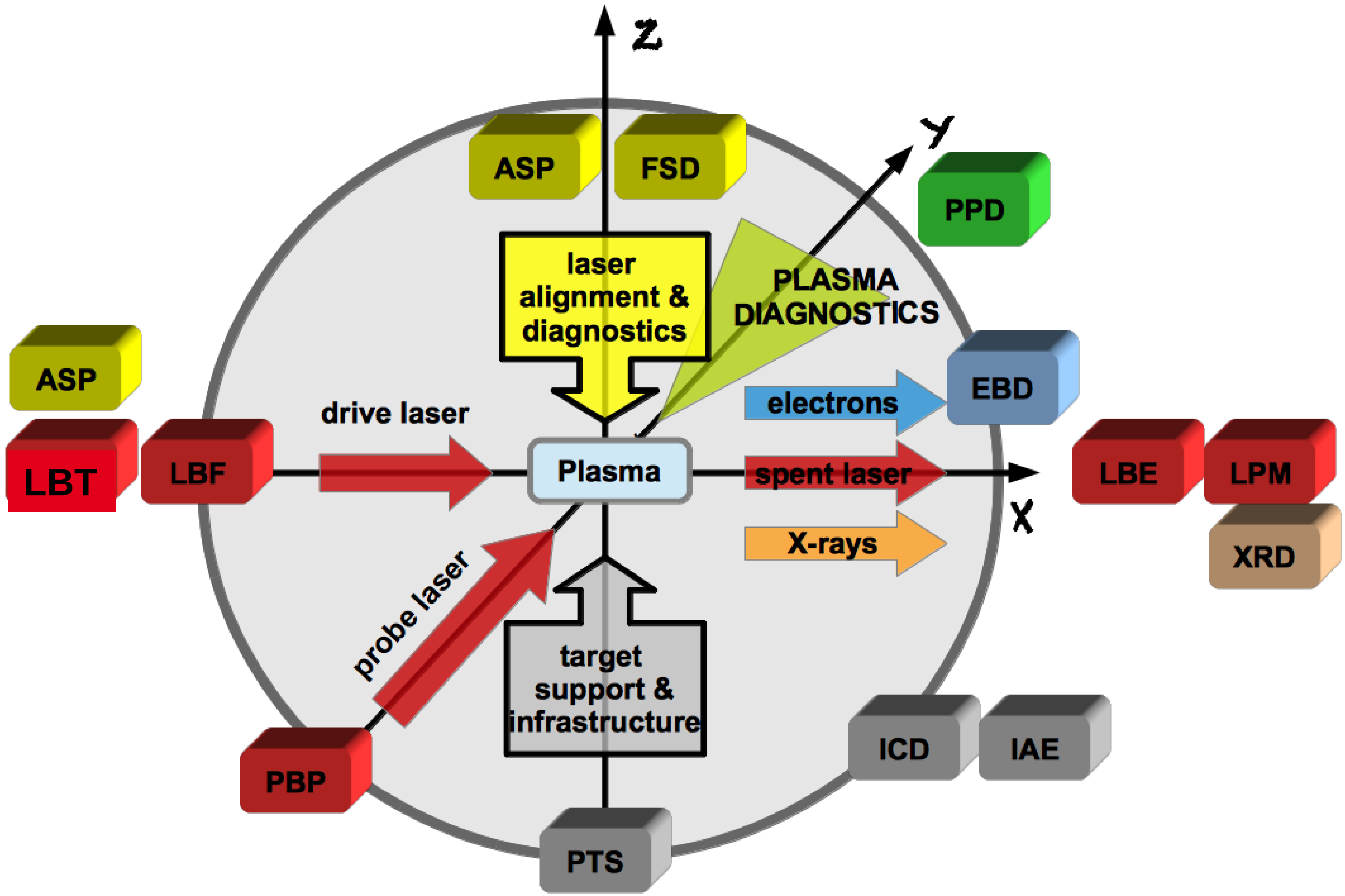
Apollon electron diagnostics: baseline design specifications

- **E measur't with moderate resolution (~5%)** over wide range
- **E measur't with good res. (~1%)** over narrow, adjustable range
- **sufficient angular acceptance (~50mrad)**
  - RMS divergence 3mrad -> +/- 3 sigma : ~20mrad
  - RMS pointing fluctuation 3 mrad -> +/- 3 sigma : ~20mrad
  - compatible with max. laser opening angle (F/20 : 50 mrad)
- **provide point/line focus for source imaging / transv. ε measur't**
- **possibility to extend to higher energies (modularity)**
- **compactness, low power consumption**
- **compatibility with phosphor/scintillator screen detector**
- **IA2 only: exit port at inj. *p* (~200MeV/*c*) for 2-stage exp's (EBT)**

- **main assets of long focal area at CILEX**
  - 2 independent experimental areas
  - variation of focal length : I_0 w_0 matching
  - modular ergonomic chambers
  - variety of plasma targets and setups possible
- **Your input, help and collaboration of LWFA of electrons is welcome**
- **Exploit flexibility to implement new schemes/setups**
- **Help prioritize future evolutions of the facility**

Extra slides

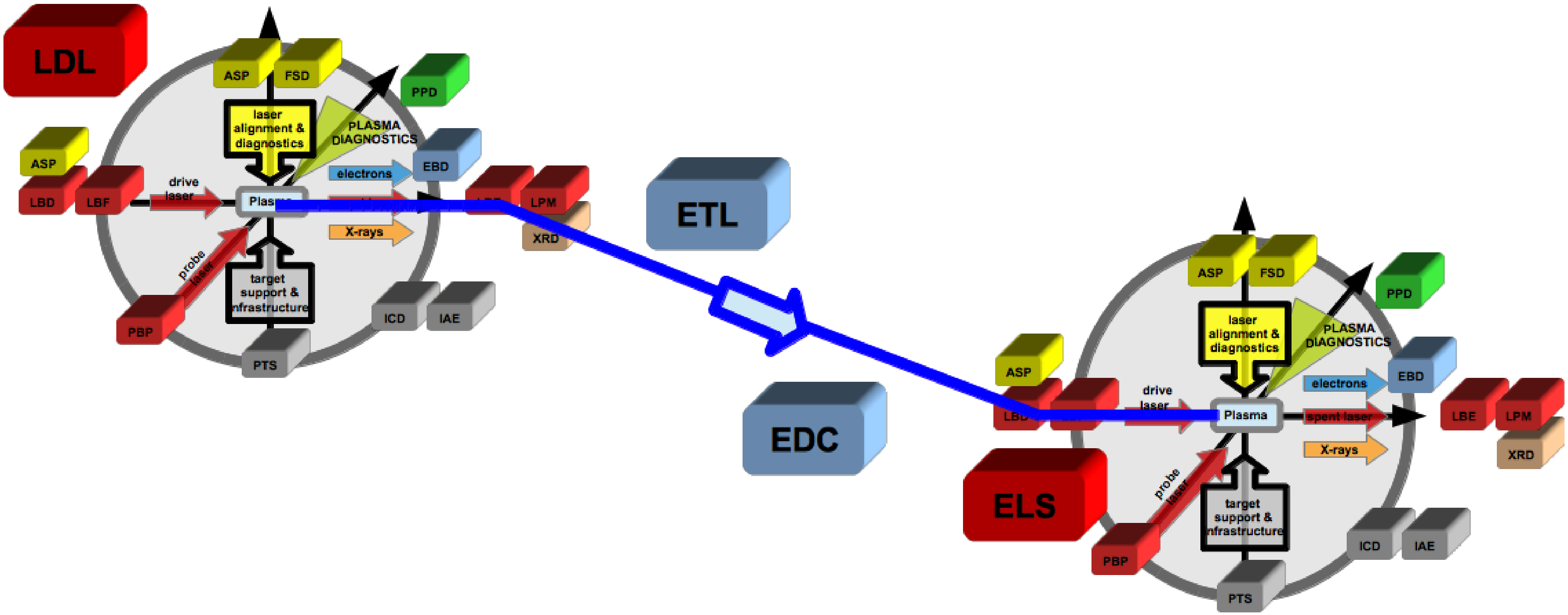
Reminder: space occupation around each IP



Reminder: work packages for each interaction area

- **Laser beam transport (LBT)**
- **Laser beam focusing (LBF)**
- **Probe beam preparation (PBP)**
- **Focal spot diagnostics (FSD)**
- **Alignment system and procedure (ASP)**
- **Plasma target support (PTS)**
- **Proximal Plasma Diagnostics (PPD)**
- **Interaction chamber design (ICD)**
- **Interaction Area equipment (IAE)**
- **Laser beam ejection (LBE)**
- **Laser post mortem diagnostics (LPM)**
- **Electron beam diagnostics (EBD)**
- **Xray diagnostics (XRD)**

Reminder: task packages for interaction area linking



- Laser beam delay lines (LDL)
- Electron beam transfer line (ETL)
- Electron beam diagnostics and control (EDC)
- Electron beam to laser synchronization (ELS)