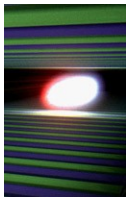


Status of RF Synchronization

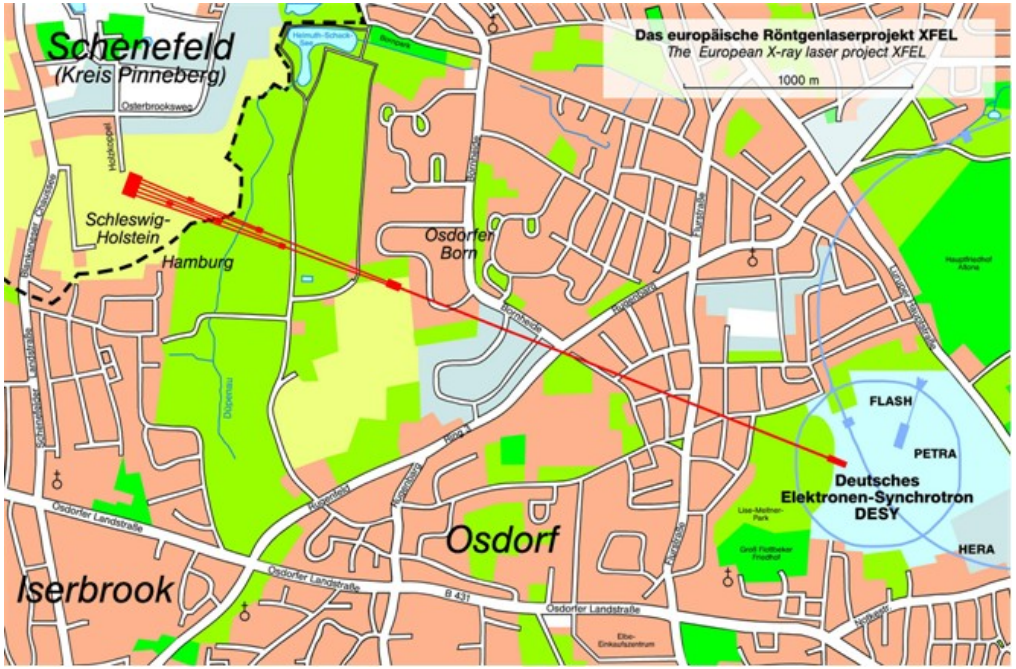
LLRF Collaboration Workshop

WUT, Warsaw, 14.12.2011

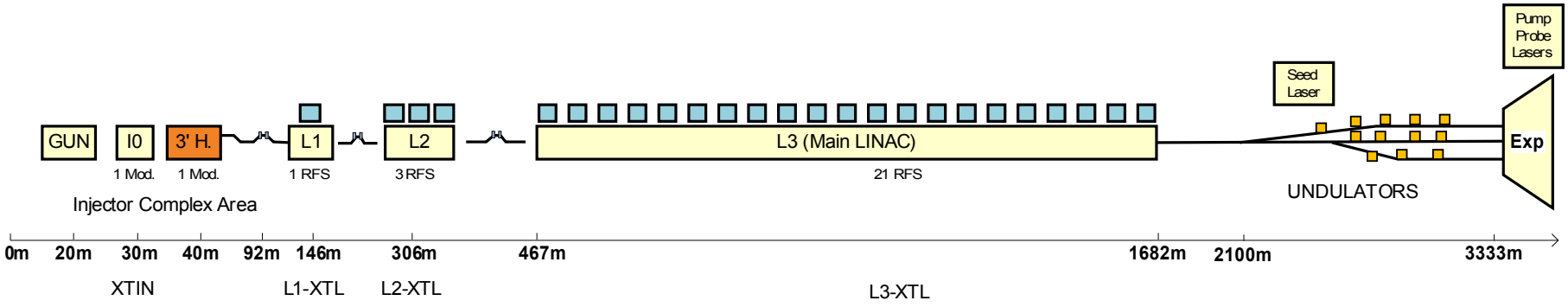
Krzysztof Czuba
ISE/WUT

European XFEL

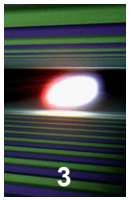
Introduction – XFEL



- 3.3km long machine
- Several thousands of digital, RF and optical devices to synchronize
- Most critical subsystems located in injector area
- Installation will start in 2013
- Commissioning planned for 2015



Field Stability Requirements for Accelerating Sections



Accelerator Section	RF Station	Amplitude Stability [%]	Phase Stability [deg]
I1 (GUN)	1300 MHz	0.01	**0.01**
I2 (Injector)	1300 MHz	0.003	**0.005**
I3 (3rd-Harmonic)	3900 MHz	0.005	**0.03**
L1 (Injector Linac)	1300 MHz	0.03	**0.03**
L2 (Booster)	3 x 1300 MHz	0.03	**0.03**
L3 (Main Linac)	20 x 1300 MHz	0.1	**0.1**

- Numbers in the last column indicate the required synchronization accuracy
  - Not straightforward! (contribution of control system components and feedback loops) but can give a good approximation
- 0.01 deg @ 1.3 GHz corresponds to roughly 20 fs of jitter

Overview of Required RF Synchronization Signals and Frequencies

WP18
10 devices, 1300MHz

Foresee RF distribution extension for upgrade linac by 5 RF stations (optional)

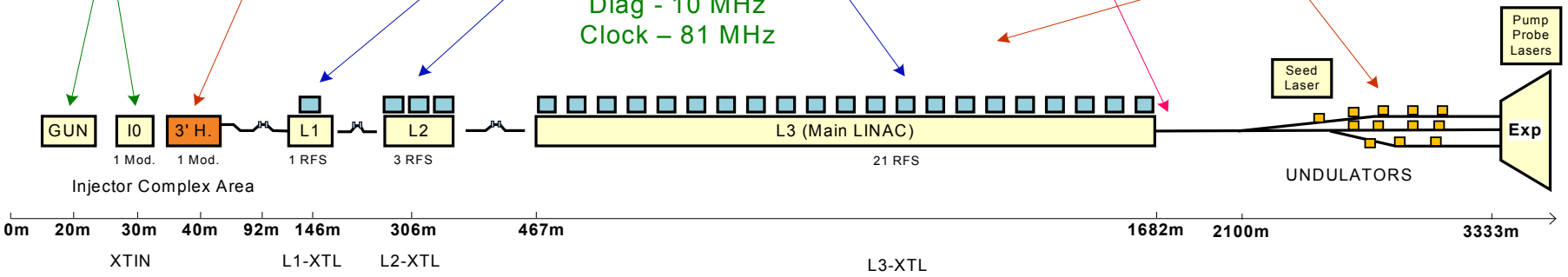
Cavity-BPM's (mostly 216 MHz)
- 4 laser heater at injector
- 6 at BC1 and BC2
- 15 between last ACC and 1st undulator
- 2 for intra bunch feedback\

216/108? MHz, +5 dBm
- 117 between undulators
- 3 after undulators

1 + 3 + 21 RF Stations
(semi-distributed = 50 tap points)
Frequencies @ each tap point:
REF - 1300 MHz
LO - 1354 MHz
BPMs - 216 MHz
BPM's - 108 MHz
Diag - 10 MHz
Clock – 81 MHz

3.9 GHz system
REF – 3900 MHz
LO – 3954 MHz
Diag – 10 MHz
Clock – 81 MHz?

Injector
REF - 1300 MHz
LO - 1354 MHz
Diag - 10 MHz
Clock – 81 MHz



LO signals will be generated within the LLRF system (F. Ludwig and cooperators)

Short Summary of Required Tap Points

LO, precise clocks and other locally generated and distributed signals not included here but also of concern for the RF distribution

1300 MHz @ injector (timing, MLO, ….)

20 x1300 MHz, +10 dBm
* 10 to 100fs jitter
* 100 fs drift

10 x 108 MHz and 216 MHz,
* 50 to 100 fs jitter, drift ?

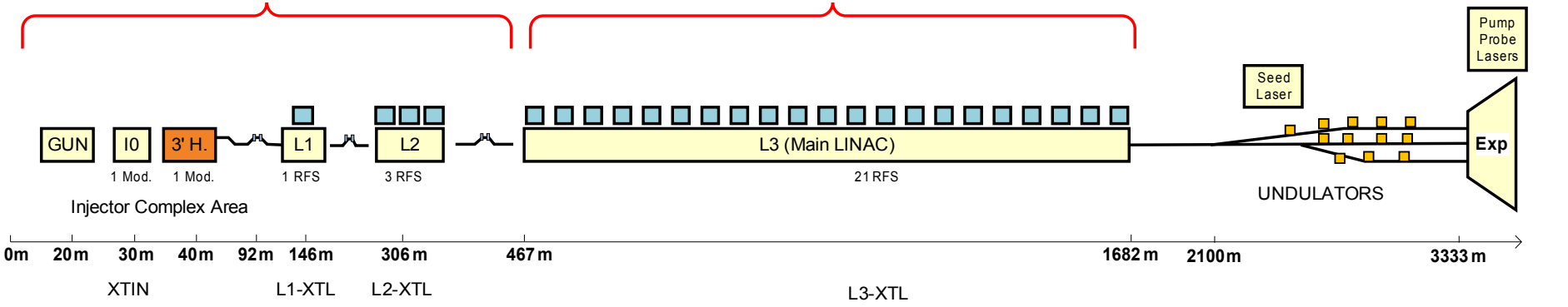
8 x 10 MHz

21 x1300 MHz,+10 dBm
* 50 to 100fs jitter
* 5 ps drift

21 x 10 MHz
+ 5 spare

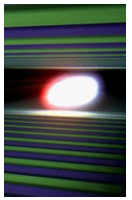
5 x1300 MHz +10 dBm
* 100 fs to 1ps jitter
* 10 ps drift

137 x 216 MHz,
* **100 fs to 100 ps jitter and drifts**



Together more than 220 tap points of various frequencies

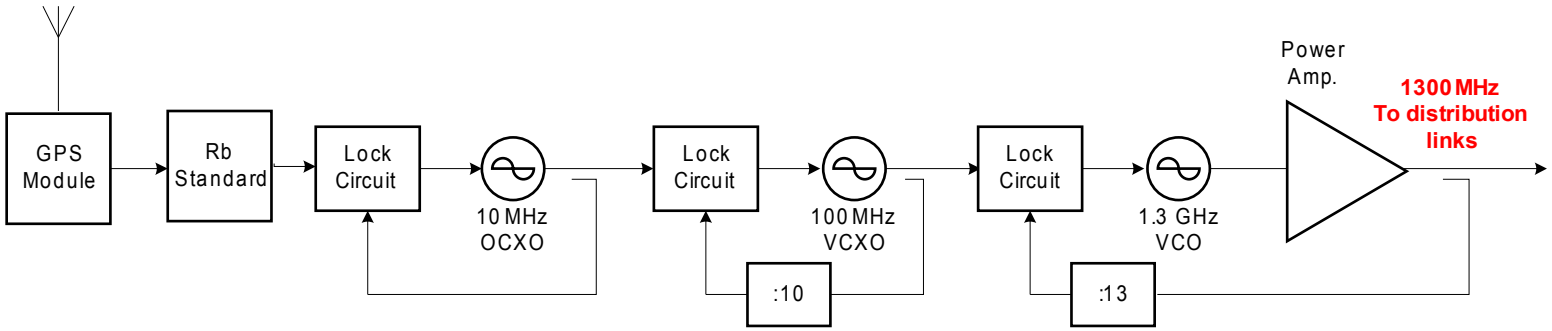
What is to be Done (overall)



1. Master Oscillator System (Ł. Zembala, H. Weddig)
2. Long distance frequency distribution links (D. Sikora, K.Czuba)
3. Local distribution at RF stations

Master Oscillator

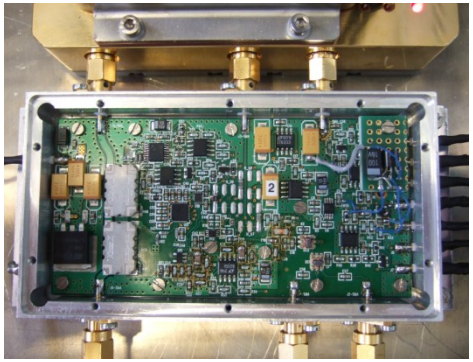
- Single frequency (1300 MHz) highly phase stable RF source
- GPS locked
- Redundant
- Introducing high power amplifier (>44 dBm) and diagnostics
- Power splitter at MO output will be the very reference for the entire XFEL (including MLO and timing system)



Rugh operating principle. Detailed design to be published within months

Master Oscillator – To Do List (1)

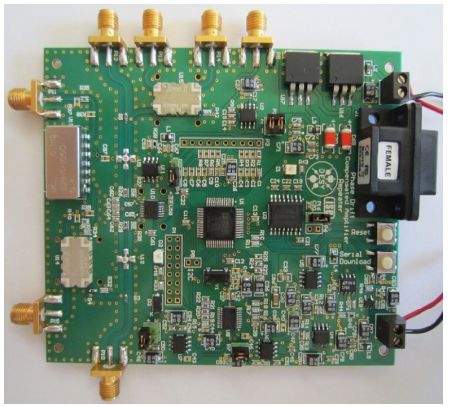
- **Prepare CDR and specification documents (becomes very important now)**
- **Design extremely low noise reference module prototype**
  - Good experience from FLASH MO. Demonstrated ~30fs absolute jitter
  - New version under development (talk of. Ł. Zembala on Thursday)
  - Work delayed mostly due to other more important tasks performed by people



- **Work out phase coherent switching (for redundancy)**
  - Still open issue on how to build it to maintain phase coherence (on fs level) in case of failure of one of reference modules

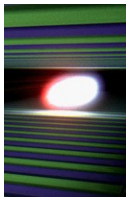
Master Oscillator – To Do List (2)

- **Design phase compensated high power amplifier**
  - Good experience from FLASH MO with high power modules. S. Jabłoński developed phase compensation circuit. Demonstrated drift reduction from 350 fs/K to 34 fs/K
  - Precise power level specification will be possible after detailed design of long distance distribution links



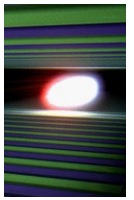
- **Work out battery based power supply and diagnostics**
- **Put all developed parts together and design MO System**
- **Prepare test, installation and commissioning procedure**

Master Oscillator – To Do List (3)



- Build final system prototype
- Test in laboratory
- Install and commission at XFEL injector area.

MO Interfaces to Other Subsystems



- **Reference for optical synchronization (power level unknown, minor issue)**
- **Reference for timing system**
- **Outputs to the long distance RF distribution**
- **Diagnostics**
  - Ethernet communication module and DOOCS servers needed
  - TMCB? Previous experience shows that digital boards can produce a lot of interference for the MO parts. Must investigate TMCB for EMI!

European XFEL

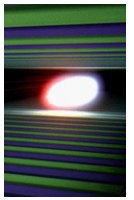
Main Difficulties and Plans

- Put all parts together and coordinate the work effectively
- “Paper” and conceptual work not disturbed by other tasks
- Except the phase coherent switch there is no issue that we haven't investigated until now and foresee big problems

Plans

- Finish new PLL prototype tests and create backbone of documentation by end Febr. 2012
- Build prototype of XFEL-like reference source by June 2012
- Purchase components, build system prototype (including diagnostics, UPS...) and finish documentation by end 2012
- Installation in XFEL by mid. 2013

Long Distance Frequency Distribution



- Assumed coax cable as a main distribution media (simple, robust, high reliability, passive distribution but high loss)
- Tap points along the distribution line to local distribution at stations
- 1300 MHz distribution along the LINAC
- 216 MHz distribution along undulators
- Phase compensated amplifier repeaters

Frequency Distribution – To Do List (1)

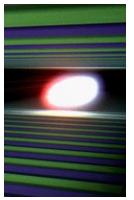
- Identify user requirements (frequencies, power levels and signal stability), find locations of tap points
- Select proper cables, directional couplers and power splitters for the system
- Calculate link power loss and drift budget
- Design the layout of the system
  - Interfaces to optical synchronization
- Experiments with selected components
- CDR and all necessary documentation
- Installation and commissioning

Frequency Distribution – Status and Main Difficulties

- **Identification of user requirements** still in progress but quite advanced
- **Gathered a lot of information about cables and other components**
- **Detailed tests of "thick" cables necessary**
- **Scheme of phase drift compensation (recent developments by P. Kownacki and G. Moeller) + new idea from SLAC**
- **Interfacing to optical synchronization – still open issue...**
- **How to verify system performance?**

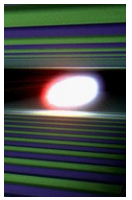
Talk by D. Sikora on Thursday

Local Frequency Distribution



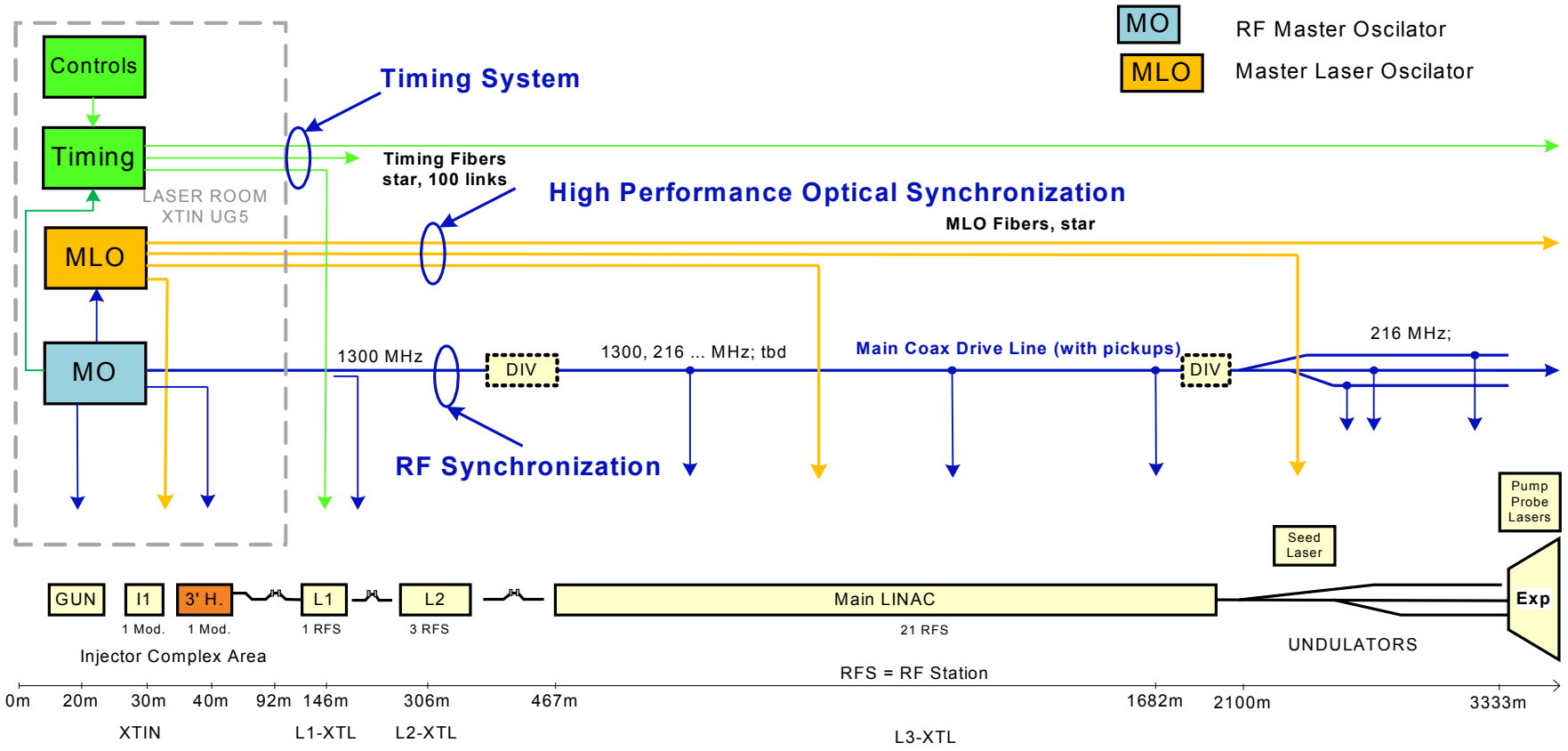
- **Issue of providing signal from tap point to the RF Reference Box - few meters of cable - contact with W. Wierba**
- **Little unclear power level value (for DCM)**
- **Build RF Reference Box**
  - Main output 1300 MHz to DCM and LOGM
  - Drift compensated amplifier (+30 dBm)
  - Frequency dividers for other frequencies
  - Diagnostics (TMCB)
- **Investigate carefully signal performance over the RF Backplane**

Thank you for attention!

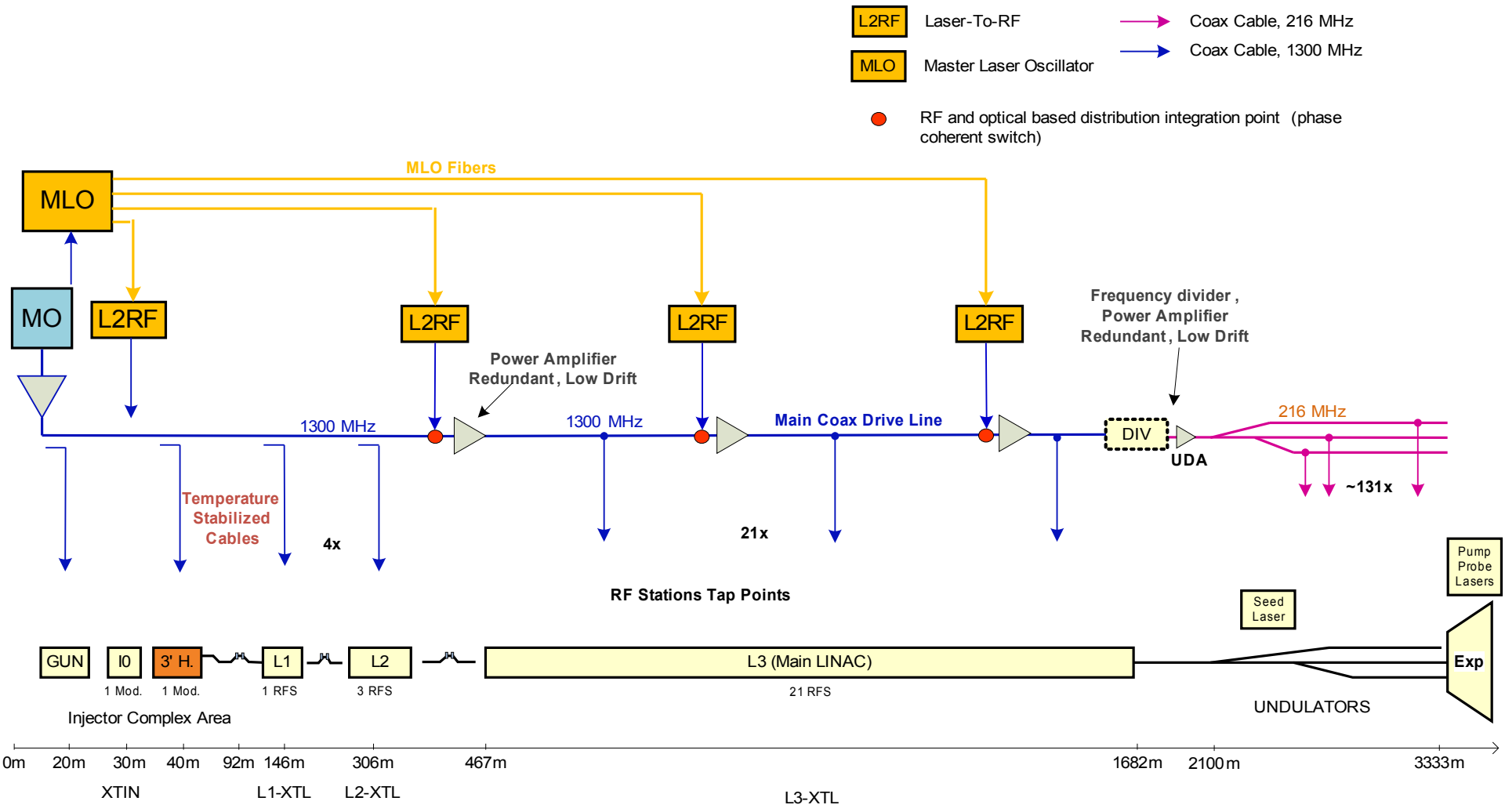


BACKUP SLIDES

XFEL Synchronization System Layout (General)

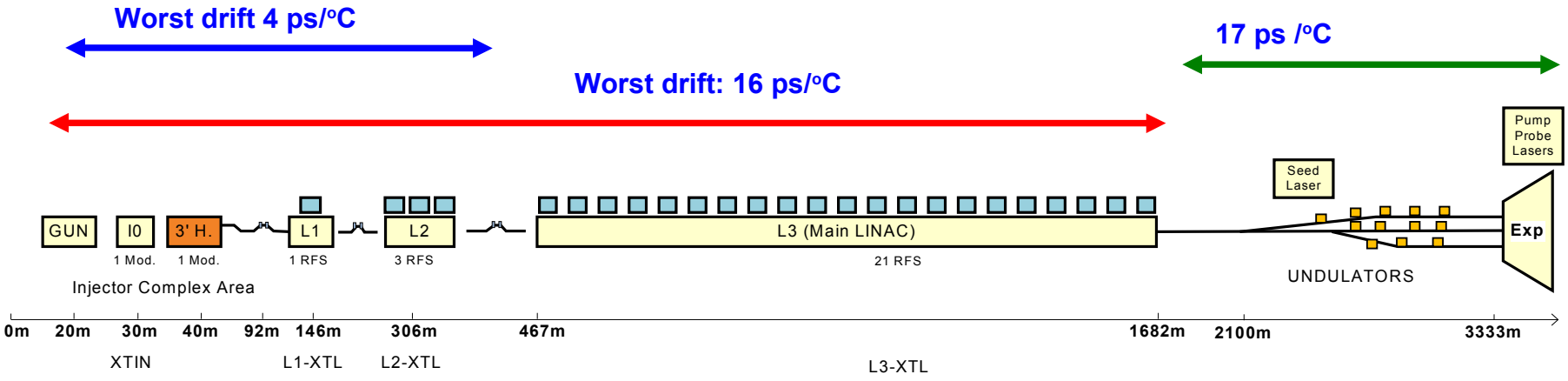


Main RF MO Distribution Scheme



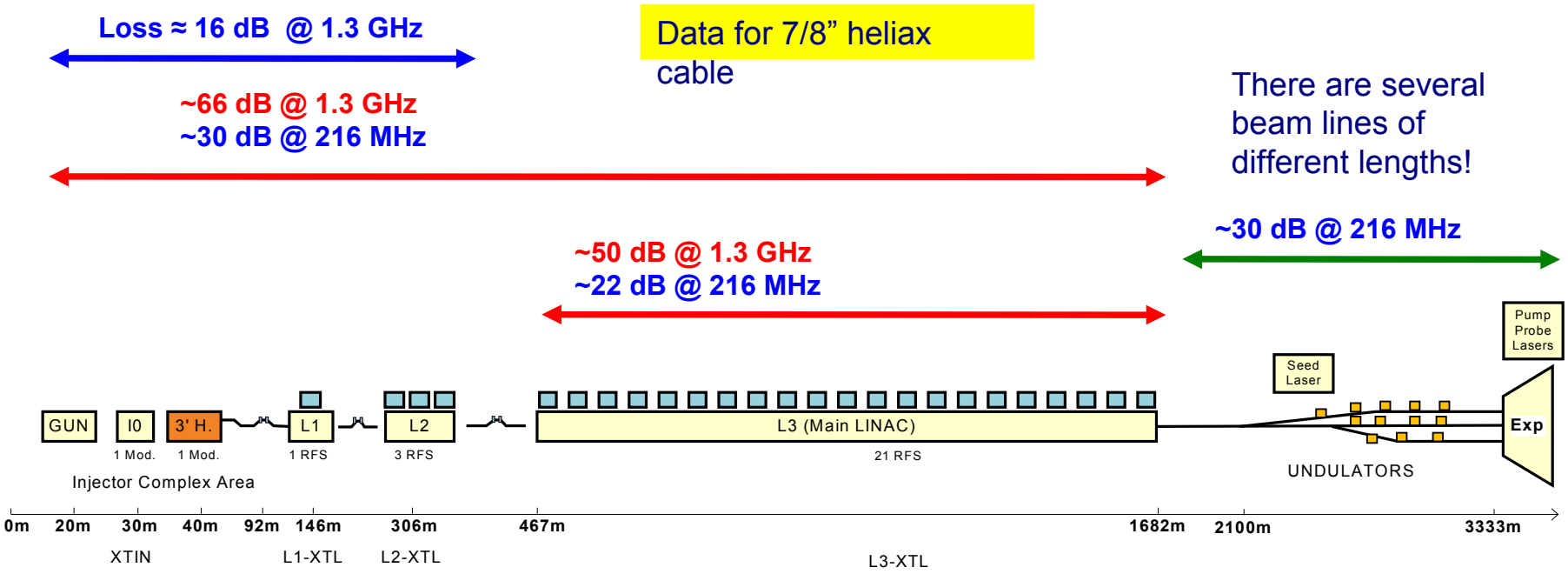
Phase Drift Estimation

Data for 7/8” heliax cable



- During stable machine operation tunnel temperature can be kept within 2 °C (Joerg Eckoldt) but temperature profile is quite complex and it is difficult to estimate drifts more precisely
- Both reflectometer scheme and temperature stabilization are considered for critical locations (Injector area and maybe L1, L2)

Estimated RF Loss in Cables



There will be 1300 MHz distribution up to L2 and 216 MHz after Main LINAC
Two scenarios considered for Main LINAC:
1. Distribution of 1300 MHz with amplifier repeaters
2. Distribution of 1300 MHz by low-loss cable

Low loss cables (diameter >1") must be investigated, (D. Sikora) and amplifier repeaters (S. Jabłoński) to make it possible to take furhter decisions.